Weeds

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NUMBER 1

Journal of the Association of Regional Weed Control Conferences

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Editorial

In assuming the duties of Editor of WEEDS the undersigned shall attempt to place the journal on a firm publication schedule and shall encourage submission of papers involving all aspects of weed control, including research, regulatory and extension. WEEDS will not compete with the Proceedings of Regional Weed Control Conferences for papers since the Proceedings normally publish progress report type papers. These are not considered appropriate for WEEDS. This journal will continue to accept only high caliber papers that are a credit to the profession of weed control. The Editorial Board will share in the duties and responsibilities for continuing this journal as a vigorous publication devoted to the requirements of workers in the field of weed control. The Editor will at all times welcome suggestions for improving this journal.

The invitational papers that were presented at the First National Weed Control Conference at Kansas City, December 8 and 9, 1953, will appear in this Journal. In many instances they will be published as they were presented with only minor editorial changes.

Title Pages, Tables of Contents and Indices for Vol. I and Vol. II will appear in an early number of Vol. III.

One of the most serious bottlenecks in processing manuscripts is occasioned by a single manuscript being reviewed by two reviewers in turn. Authors are requested to submit two complete manuscripts in order to expedite processing.

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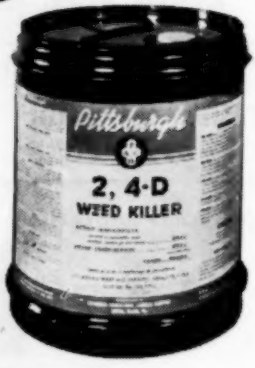

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Weeds

JOURNAL OF THE ASSOCIATION OF REGIONAL WEED CONTROL CONFERENCES.

VOLUME III JANUARY 1954 NUMBER 1

Effects of Water Upon the Movement of Dinitro Weed Killers in Soils[1]

FRANKLIN L. DAVIS and FRANK L. SELMAN[2]

THE main factor determining the effectiveness of dinitro pre-emergence weed killers in the control of annual grasses and weeds is its distribution and concentration in the soil.

Dinitro is applied as a spray to the soil surface on a 10- to 16-inch band over the row immediately after planting. Its greatest effectiveness is usually thought to occur when light rainfall moves it into the top one-fourth to one-half inch of soil. Heavier rainfall may leach the dinitro deeper into the soil, especially in light-textured, sandy soils that frequently contain only small percentages of organic matter. Leaching of the dinitro from the surface one-fourth to one-half inch of soil to greater depths may result in poor weed control and may injure the roots of the cotton or other crop seedlings.

Dinitro pre-emergence weed killers are manufactured with different formulations that vary in water solubility. The experiments reported herein were initiated to determine whether the water-solubility of the original dinitro formulations affects their movement in the soil by leaching and to study the effects of soil properties upon the movement of water and dinitro weed killers in the soil.

There is very little published information concerning the effects of formulation and soil properties upon the movement of dinitro herbicides in soils by water or rainfall. Aldrich (1) studied the effect of herbicidal formulation and application in oil and water on the leaching and persistence of dinitro-o-secondary butyl phenol and 2,4–D in soil and reported that application of both DNOSBP and 2,4–D in oil as compared to application in water did not significantly reduce stands of test crops. In studying the toxicity of certain herbicides in soils, Crafts (2) leached the materials into fairly large quantities of soils in columns. He reported on the relationship of dinitro concentrations in the soil to its toxicity to oats in California soils.

[1]Contribution from the Alabama Polytechnic Institute Agricultural Experiment Station. Published with approval of the Director. The work reported herein was supported in part by a grant of funds by the Dow Chemical Company, Midland, Michigan.

[2]Soil Chemist and Laboratory Technician.

He also reported that the toxicity of sodium dinitro-o-cresylate is more definitely related to textural grade than to fertility, and that the chemical is retained against leaching by soils of high colloidal content.

MATERIALS AND EQUIPMENT

Dinitro Materials. Six different formulations of dinitro materials were used. The group consisted of three oil-soluble and three water-soluble formulations. The oil soluble formulations were a proprietary formulation containing DNOSBP, (2-secondary butyl, 4, 6-dinitro phenol), known as Dow General, and two similar formulations varying in emulsifying agent content. The water-soluble formulations were a proprietary formulation containing the alkanolamine salts of DNOSBP, known as Premerge, and two similar formulations varying in content of a surface active agent added to improve spraying qualities. The designation and composition of each of the materials used are shown in Table 1.

Table 1. Composition of herbicides.

Designation of material	Formulation	Wetting Agent	DNOSBP Content
Composition A	Dow General	Normal amount	56% by weight (5 lb. per gal.)
Composition B	Dow General	None	56% by weight (5 lb. per gal.)
Composition C	Dow General	4 times normal amt.	56% by weight (5 lb. per gal.)
Composition D	Premerge	Normal amount	3 lb. per gal.
Composition E	Premerge	None	3 lb. per gal.
Composition F	Premerge	10 times normal amt.	3 lb. per gal.

The DNOSBP formulations of the Dow General type are oil-soluble, water-miscible liquids. The preparations containing the alkanolamine salts of DNOSBP are water soluble. In this study, compositions A, B, and C were applied to the soil as 1000 ppm of DNOSBP solutions in kerosene, and compositions D, E, F, in water solutions of the same concentration of DNOSBP.

Soils. The leaching studies described herein were carried out on three soils of different texture. These were namely, Norfolk sandy loam, Deer Creek silt loam, and Kaufman silty clay loam. The physical analysis of these soils are shown in Table 2.

Table 2. Physical analysis of soils.

Soil Separate	Size limit mm.	Norfolk sandy loam %	Deer Creek silt loam %	Kaufman silty clay loam %
Very coarse sand	2.0 –1.0	6.6	0.1	0.3
Coarse sand	1.0 –0.5	21.4	0.3	3.1
Medium sand	0.5 –0.25	11.0	0.1	3.3
Fine sand	0.25–0.10	31.5	1.6	11.0
Very fine sand	0.10–0.05	8.1	13.0	7.6
Total sands	2.0 –0.05	78.6	15.0	25.3
silt	0.05–0.002	15.0	68.2	52.6
clay	–0.002	6.4	16.8	22.1
Totals		100.0	100.0	100.0

Certain determinations of some chemical properties related to the fertility of the soils were also made and are given in Table 3.

Table 3. Chemical analysis of Soils.

Soil Type	Organic matter content %	Soil reaction pH	Cation exchange capacity m.e./100g	Exchangeable Ca m.e./100g	Percentage calcium saturation %	Exchangeable K m.e./100g	Exchangeable Na m.e./100g
Norfolk sandy loam.....	1.14	6.00	2.51	1.25	49.8	0.153	0.182
Deer Creek silt loam.....	0.81	5.65	14.16	9.62	67.9	0.425	0.326
Kaufman silty clay loam...	2.02	6.30	16.35	13.81	84.5	2.94	0.256

Equipment. The leaching of the dinitro into the soil was done in cylinders having an inside diameter of 3-1/8 inches. These cylinders were mounted on sectioning apparatus shown in Figure 1. These apparatus were iron tripods with a circular base welded onto the legs near the top. The circular base was drilled and threaded at the center to take a 3/8-inch bolt having 16 threads to the inch. A removable piston was mounted on the top of the bolt. This sectioning equipment permitted the upward removal of the soil from the cylinders in sections of any desired thickness.

A polyethylene reagent bottle having minute holes drilled in the bottom was used, as illustrated in Figure 1, to supply the desired amount of water as simulated rainfall. A Beckman Model B spectrophotometer was used for the quantitative determination of the dinitro phenol.

Analytical Methods

The mechanical analyses of the soils were made by the method described by Olmstead *et al.* (4). The organic matter contents of the soils were determined both by wet oxidation with hydrogen peroxide (1) and by determination of the total carbon. The soil pH was measured with a Beckman Model G pH meter in a 1:1 soil-water suspension. The cation exchange capacities of the soils were determined by the method of Peech *et al.* (5). Exchangeable cations were extracted by the above method (5) and determined with a Perkins-Elmer flame photometer.

The dinitro phenol contents of the soil sections were determined after separation of the herbicide from the soil by steam distillation. The soil, distilled water, and 10 ml of 10% phosphoric acid were placed in the distilling flask and the distillate was collected in volumetric flasks containing 1 ml. of 1% NaOH solution per 100 ml. volume. The concentration of dinitro in known volumes of distillate was determined by measuring the percentage transmission of light at 390 Mu.

Experimental Procedure

Approximately a half bushel of each of the soils was brought into the laboratory, air dried, and passed through a sieve to remove particles larger than 2.0 mm. in diameter. Each of these lots of soil was mixed and used for subsequent leaching studies.

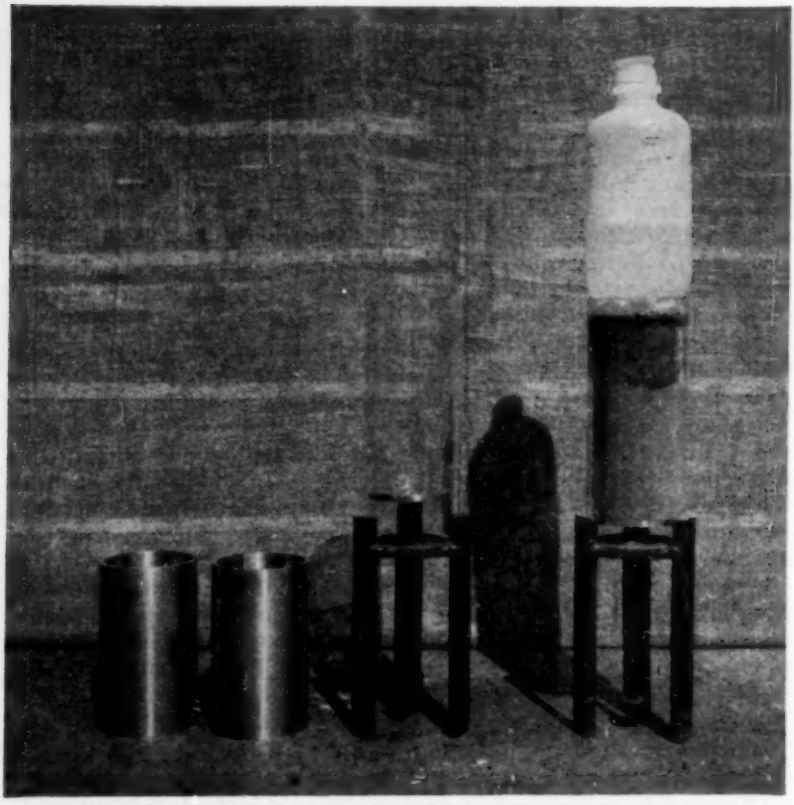

FIG. 1. Cylinders, polyethylene watering bottle and soil sectioning apparatus.

The desired number of tubes on the sectioning tripods was filled with soil, and the soil was uniformly settled by tamping lightly with the hand. The soil used for filling the tube was usually passed through a soil quartering device to insure uniform mixing of the granulated soil particles throughout the soil column. The amount of a 1 gm. per liter of dinitro solution required to equal 9 pounds per acre was then uniformly distributed over the surface of the soil by dropping from a measuring pipette having a capillary-size opening. This concentration of dinitro is more dilute than that customarily used for field application, but it was necessary to obtain coverage of the dry soil surface. After application of the dinitro, the desired amount of water was applied to the soil by allowing it to drip from the perforated bottom of a polyethylene bottle placed on the top of the cylinder. The rate at which the water dripped onto the soil was 2 inches in 12 minutes. After standing overnight, the treated and watered columns of soil were removed from the tubes in ¼- or ½-inch sections, and the dinitro content of each section

was determined. All leaching tests were completed on duplicate samples.

Stainless steel cylinders 6 inches long were used for the first leaching tests. It was found that 1 inch of water wetted the column of soil accommodated by these tubes to the bottom and that 1½ and 2 inches of water ran out the bottom of the tubes and left the soil soggy. In order to use more than 1 inch of water and to determine the rate of movement of the water into the soil, 8¾-inch transparent lucite tubes were used for all leaching determinations with 2 inches of water. Both kinds of tubes are shown in Figure 1. Three scales showing ¼-inch divisions were inscribed on the outer surface of the lucite tubes at distances of about 120° apart. These three scales were used for observations to determine the average rate of percolation of the applied water into the soil.

RESULTS

Data on the amount of dinitro added and its distribution in duplicate columns of Norfolk sandy loam after being leached into the soil with ½, 1, and 1½ inches of water are given in Tables 4, 5, and 6, respectively. All of these tests were run in the 6-inch steel cylinders.

The distribution of the dinitro in the soil from the compositions D, E, and F that contained different amounts of wetting agent showed very little difference from the same amount of added water. The duplicate determinations of dinitro when leached with ½ inch of water were in good agreement and the relative distribution through the soil was similar for all three compositions. The results obtained from adding 1-inch of water showed slightly more movement of compositions containing the wetting agent, i.e., D and F, then of composition E. This difference, however, was confined to leaching of the dinitro from the surface ¼-inch layer of soil, with somewhat more dinitro at the ½- to 1-inch depth. The amount of dinitro in all other soil sections was comparable. This apparent effect of the wetting agent on the movement of dinitro did not occur when 1½ inches of water was applied.

There was a small increase in the magnitude of the average differences between the amounts of dinitro recovered from duplicates as the amount of water applied was increased.

All laboratory tests of leaching with 2 inches of water were run in duplicate in the 8¾-inch lucite tubes. The depths to which the water had penetrated the soil were observed at definite time intervals and recorded. The average rate of downward movement of water and the average content of dinitro recovered from ¼-inch sections of soils are shown graphically in Figures 2 and 3. The data for compositions A, B, and C are presented in Figure 2 and for compositions D, E, and F in Figure 3.

DISCUSSION

The preliminary studies of the leaching of compositions D, E, and F in Norfolk sandy loam with ½, 1, and 1½ inches of water did not show any consistent differences in the extent of movement into the

soil of the dinitro from the three different experimental formulations. Consequently, the 2-inch rate of water was used in the subsequent studies.

The leaching of larger amounts of dinitro from the top ¼-inch layer of soil (Table 6) into a 24-inch column as compared to a 6-inch column undoubtedly resulted from a slowing down of the rate of movement of water in the shorter column of soil. This did not occur in the longer, i.e. 8¾-inch, lucite cylinders.

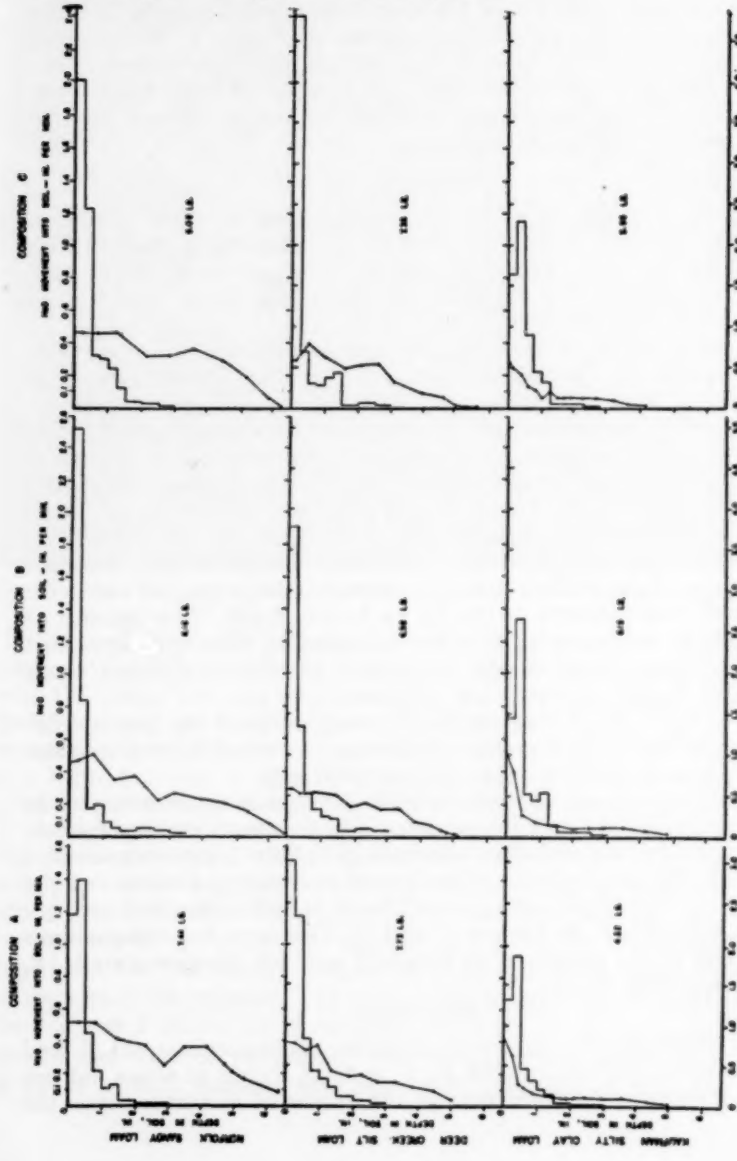

FIG. 2. The rate of movement of 2.0" of water into the soil and the resulting distribution of oil-soluble dinitro in three soil types.

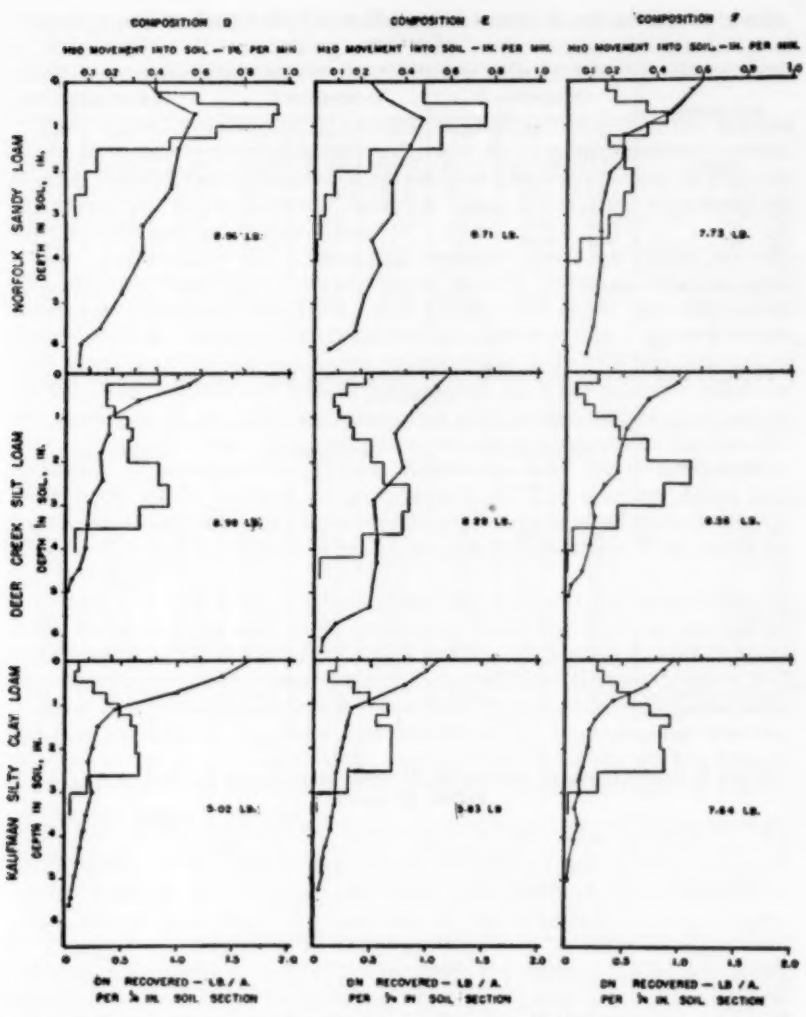

FIG. 3. The rate of movement of 2.0 inches of water into the soil and the resulting distribution of water-soluble dinitro in one quarter inch sections of three soil types.

The movement of dinitro from the water-soluble forms, i.e. compositions D, E, and F, in the Deer Creek and Kaufman soils appeared to be related to the rate of movement of water into these soils. This is shown graphically in Figure 3. The dinitro was largely leached from the top 1 to 1¼ inches of soil through which the water moved at a rapid rate, i.e. about 0.2 inch or more per minute. It is probable that practically all of the water added flowed as free gravitational water through this depth. The largest concentrations of dinitro remained in those layers of the soil through which the

Table 4. **Distribution of dinitro in Norfolk sandy loam leached with ½ inch of water.**

Soil section	Composition D			Composition E			Composition F		
	I	II	av.	I	II	av.	I	II	av.
Depth	Lb./a.	Lb./a.	Lb./a.	Lb./a.	Lb./a.	Lb./a.	Lb./a.	Lb./a.	Lb./a.
0 –¼"	4.22	4.28	4.25	3.83	3.59	3.71	4.22	4.41	4.32
¼"–½"	3.25	3.29	3.27	2.40	2.51	2.46	1.92	1.92	1.92
½"–¾"	1.19	1.28	1.24	1.49	1.44	1.46	1.41	1.27	1.34
¾"–1.0"	0.45	0.48	0.46	0.57	0.70	0.64	0.90	0.70	0.80
1.0"–1½"	0.08	0.06	0.07	0.10	0.26	0.18	0.47	0.34	0.40
1½"–2.0"	0.05	0.01	0.03	0.01	0.01	0.01	0.04	0.01	0.02
Total recovered	9.24	9.40	9.32	8.40	8.51	8.46	8.96	8.65	8.80
Amount added	9.40	9.40	9.40	9.00	9.00	9.00	9.00	9.00	9.00

Table 5. **Distribution of dinitro in Norfolk sandy loam leached with 1.0 inch of water.**

Soil section	Composition D			Composition E			Composition F		
	I	II	av.	I	II	av.	I	II	av.
Depth	Lb./a.	Lb./a.	Lb./a.	Lb./a.	Lb./a.	Lb./a.	Lb./a.	Lb./a.	Lb./a.
0 –¼"	1.84	1.85	1.84	2.58	2.71	2.65	1.47	1.86	1.67
¼"–½"	1.92	2.08	2.00	2.03	1.73	1.88	1.76	1.93	1.84
½"–¾"	1.82	2.10	1.96	1.56	1.39	1.48	2.01	2.10	2.06
¾"–1.0"	1.54	1.55	1.55	1.19	1.21	1.20	1.69	1.54	1.61
1.0"–1½"	1.40	1.32	1.38	1.06	1.19	1.12	1.54	1.27	1.41
1½"–2.0"	0.20	0.18	0.19	0.23	0.23	0.23	0.28	0.12	0.20
2.0"–2½"	0.04	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.03
2½"–3.0"	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02
3.0"–3½"	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01
Total recovered	8.78	9.15	8.98	8.72	8.54	8.63	8.81	8.88	8.85
Amount added	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00

Table 6. **Distribution of dinitro in Norfolk sandy loam leached with 1½ inches of water.**

Soil section	Composition D						Composition E			Composition F		
	In 6" tube			In 24" tube*			In 6" tube			In 6" tube		
	I	II	av.	I	II	av.	I	II	av.	I	II	av.
Depth	Lb./a.			Lb./a.			Lb./a.			Lb./a.		
0 –¼"	1.54	1.58	1.56	0.68	1.25	0.97	1.61	1.22	1.42	1.54	1.89	1.72
¼"–½"	1.44	1.28	1.36	0.75	1.35	1.05	1.44	1.61	1.52	1.34	1.50	1.42
½"–¾"	1.33	1.36	1.34	1.16	1.52	1.34	1.55	1.65	1.60	1.44	1.45	1.45
¾"–1.0"	1.31	1.30	1.31	1.47	1.52	1.50	1.42	1.50	1.46	1.31	1.28	1.30
1.0"–1½"	1.92	1.94	1.92	2.36	1.55	1.95	1.84	1.76	1.80	1.92	1.65	1.78
1½"–2.0"	0.86	0.92	0.89	1.08	0.38	0.73	0.65	0.69	0.67	0.91	0.72	0.81
2.0"–2½"	0.18	0.15	0.17	0.33	0.10	0.21	0.12	0.18	0.15	0.22	0.15	0.18
2½"–3.0"	0.02	0.02	0.02	0.09	0.04	0.06	0.02	0.04	0.03	0.02	0.02	0.02
3.0"–3½"	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
Total recovered	8.63	8.57	8.60	7.94	7.73	7.83	8.67	8.66	8.66	8.71	8.67	8.69
Amount added	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00

*Four 6-inch steel tubes taped together at joints.

water initially moved at a rate of 0.1 to 0.2 inch per minute. Movement of dinitro into the soil stopped at the depth in the soil, (about 4 inches in the Deer Creek silt loam and 3 inches in the Kaufman silty clay loam), at which the rate of movement of the water into

soil dropped to less than 0.1 inch per minute. Thus, under field conditions a very slow drizzling rain may cause much less leaching of dinitro into the soil than a short, heavy rain having the same total precipitation.

Under field conditions, observations indicate that dinitro leaches more in coarse-textured sandy soils low in organic matter content than it does in finer-textured soils such as silty clay loams. It did not do so in the Norfolk sandy loam in these laboratory experiments. The reason for this is not known.

The presence or the amount of wetting agent in either the oil-soluble formulations (compositions A, B, and C) or the water-soluble materials (compositions D, E, and F) did not show any consistent effect upon the movement of the dinitro into the soil. Figure 2 shows that there was less dinitro from composition A in the top ¼-inch of all soils than there was from composition B. This possible effect of the presence of the wetting agent did not extend below the top ½ inch of soil for these two materials, nor was it apparent in the distribution of composition C that contained four times the amount of wetting agent present in composition A. The wetting agent had no apparent effect upon the movement of the water-soluble materials (Figure 3) with the possible exception of composition F in the Norfolk sandy loam.

There was definitely a smaller amount of total dinitro recovered from the Kaufman silty clay loam than from the Norfolk and Deer Creek soils in most instances. The graphs in Figure 2 and 3 show that the largest reduction usually occurred in the top ¼-inch soil section, to which the dinitro was applied. The dinitro was apparently held by the soil in an unrecoverable form. The reasons for this are not known, although one might expect from the data on the chemical composition of the soil that it is related to the amount or nature of the soil organic matter.

Under the conditions in which the dinitro was applied to the soil in these laboratory experiments, the largest differences observed were related to the solvent used. The oil-soluble compositions A, B, and C were applied in kerosene and the water-soluble compositions, D, E, and F were applied in water solutions. The water as simulated rainfall was applied immediately after the dinitro. The kerosene, which was the solvent for compositions A, B, and C, apparently prevented dissolution of the dinitro in the water. This prevention of leaching by an oil solvent would probably not be as pronounced under field conditions where the kerosene would likely have a day or two to evaporate before rainfall occurred. However, the data suggest the possibility than an oil-soluble formulation applied in kerosene or other oil solvent might give better weed control on light-textured, sandy soils when application of the dinitro is likely to be followed by heavy rains.

SUMMARY

A method and technique of studying the effect of water on the movement of dinitro-phenol herbicides in soils is described.

The movement and consequent distribution of dinitro-o-secondary butyl phenol in the soil is affected by the texture of the soil, the amount of water added, and the formulation of the dinitro herbicides. One of the soils studied was found to retain in an unrecoverable form as much as 50% of the dinitro applied.

The results obtained showed that the oil-soluble, water-miscible form, DNOSBP, was moved much less in the soil by water than was the water-soluble form. These results indicate that the oil-soluble form may give better weed control, particularly on light-textured soils when application of the weed killer is followed prior to germination of the seed by an inch or more of precipitation.

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Some Aspects of Right-of-Way Brush Control with 2,4,5–T and 2,4–D

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CHEMICAL control of brush in right-of-ways is now a generally accepted practice. Through the recent period of development and ultimate successful use of this practice, certain important aspects of chemical control have been noted by those in the field of research and commercial use. Many of these aspects are amply documented in the literature while numerous common observations have never been recorded. In this general discussion of chemical brush control, an attempt is being made to weave both types of observations together.

FOLIAGE APPLICATIONS

Foliage spraying is the most common method of chemically controlling woody plants on right-of-ways. This type of application may be made by ground equipment using piston-type pumps and standard orchard spray guns. Foliage sprays may also be made from an airplane or from a railroad spray car. Each of these particular methods has a place in brush control and the one to be used depends upon the situation involved. Spraying with piston-type pumps mounted on four-wheel drive equipment is the standard approach to right-of-way brush control. This method is versatile, fairly economical and can be used in most of the areas where brush control is a problem.

Standard spray guns of the type generally used in orchards are most often used for actual application of the spray. The disc sizes of these guns vary from 5/64 to 8/64. Pressures should be governed by the size of disc and should be set to give a minimum of small droplets or fogging. Higher pressures may be used more safely with the larger size tips since these tips tend to produce less fog at higher pressures than small tips.

Stem Wetting

Stem wetting is essential in foliage sprays. Immature stems should be thoroughly wetted on all sides throughout the entire length of the stem. Laboratory work has demonstrated that a drop of 2,4–D or 2,4,5–T applied in one part of a herbaceous plant appears to move to the other parts of the plant, including the roots. However, it is equally well established in field work that application of spray to half of the sprouts in a clump does not kill the other half and it is necessary to wet everything that is to be killed. For this reason many contractors have adopted the procedure of spraying from the ground. This permits the sprayman to operate in close proximity to the brush and facilitates complete wetting. This practice is more

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common in right-of-ways which run across country while most brush along roadsides is sprayed from a moving vehicle.

Spray Mixture

Most spray mixtures which are now used on the right-of-way are made up with a gallon of low volatile esters (containing two pounds each of 2,4–D and 2,4,5–T) in 100 gallons of spray. However, it is interesting to note that there is a trend in some areas, at least, toward the use of 2,4,5–T low volatile esters alone and most of these are being used at three to four quarts per 100 gallons, that is three to four pounds acid equivalent as a low volatile ester. At one time, there was some concern that some species might not be susceptible to 2,4,5–T and, therefore, a mixture was desirable. However, in many areas the advantage of using 2,4,5–T for its efficiency on hardwoods has become evident and while it is apparently less active on such species as elderberry and possibly some willows, these species are not completely tolerant to 2,4,5–T and satisfactory results have been obtained. In connection with any discussion on species reaction, it is important to emphasize that the identification of woody plants beyond genera is highly desirable. Many of our woody plant reports relate results of a brush control experiment in terms of the results on a given genus which was present in the area. Owens and Willard (1) have pointed out that very definite differences exist among willows. Some willows are more receptive to applications of 2,4–D, some respond better to 2,4,5–T and some actually do not respond too well to anything. Another example of this is the ash group. In some areas ash has been reported to be fairly sensitive, whereas in most areas ash is regarded as one of the more tolerant species. The author has had excellent success in controlling black ash, both through basal sprays and foliage sprays, and yet white ash and green ash have been very tolerant. It is apparent that confusion might result if this were reported in terms of *Fraxinus spp.* It is very important for research workers to know the woody plants down to species and to report them as such and it is very helpful for the utility man to have this information in order properly to evaluate his results.

The application of foliage sprays by the use of piston-type sprayers and guns has occasionally been referred to as blanket spraying, implying that the right-of-way is wrapped in a blanket of spray in such a manner that nothing can or does survive. However, those who have been involved in this type of operation will realize that this is true only in the sense that where undesirable brush is growing it can be sprayed in such a manner as to give a maximum amount of kill of that brush. It is entirely possible, and in fact, often unavoidable to leave certain forms of low growing brush on the right-of-way whether or not their presence is thought to be desirable. Some desirable low growing species which may be killed unavoidably may be replaced by an equally valuable cover.

Timing of Foliage Sprays

The stage of growth which determines the time that the first

foliage sprays may be made in the spring is quite well defined. Very early spring applications made when the terminal growth is in a state of rapid elongation and many of the leaves are only partly functional, frequently result in a spectacular kill of these sensitive leaves and terminal twigs with rapid regrowth from stem and root-collar areas. This is a very brief period immediately following bud-break in the spring. At that time there is very likely a relatively rapid mobilization of carbohydrates from the adjacent stem areas and possibly from the roots to the newly developing structures. These rapidly expanding leaves are presumably not moving quantities of food material downward and since the movement of these herbicides is associated with the movement of food materials, the chemical is not moved to the areas which we want to kill, i.e. the roots. However, when the rate of terminal elongation has slowed down somewhat and the newly developed leaves have matured to the extent that they are producing carbohydrates in excess of their daily requirement, then applications of 2,4–D and 2,4,5–T may be expected to reach their peak efficiency. In some species such as ash this may be associated with the development of the terminal bud. From this period on through the summer, most right-of-way brush, which is generally growing from an old stump, is susceptible to 2,4–D or 2,4,5–T independent of the month or day on which it may be sprayed.

The time of year when foliage spray operations should be terminated is not well defined and not well understood. The general suggestion has been to stop spraying about two weeks before frost may be expected in a local area. Actually most contractors watch the foliage and continue to spray as long as the leaves have a healthy vigorous appearance.

Some interesting points regarding late fall spraying have developed as a result of a series of experiments on oak in Michigan. Two-year old oak sprouts were sprayed with several concentrations of 2,4,5–T and a mixture containing equal amounts of the 2,4,5–T and 2,4–D as the propylene and polypropylene glycol butyl ether ester. These treatments were started on August 31 and the final application was made on October 4. One year later the percent of sprouting was evaluated and it was evident that three pounds acid equivalent of 2,4,5–T per 100 gallons was equivalent to four pounds acid equivalent of the 2,4–D–2,4,5–T mixture.

The data from this experiment which are presented in Table 1 indicate that plants were susceptible to both materials through September 20. Normal fall coloration began shortly after September 20 and plant response to the 2,4–D – 2,4,5–T mixture was reduced. However, these oaks continued to respond to 2,4,5–T through the final spraying date even though leaves were almost completely red at that time.

This experiment was followed by a similar one applied September 22, 1953 where three-year old oak sprouts were sprayed with various mixtures at a time when leaf discoloration was well underway. The materials and mixtures used in this test are presented in Table 2.

This table also shows the mean percentage of stem-length which

Table 1. Percent of oak clumps (quercus alba and quercus ellipsoidalis) showing no live growth in October, 1951, one year following application of the indicated treatments.

Chemical	ahg.**	Plants not resprouting (%)					
		Dates of application					
		Aug. 31	Sept. 6	Sept. 13	Sept. 20	Sept. 28	Oct. 4
2,4,5-T*	2	73.2	66.0	82.9	90.2	68.2	62.0
2,4,5-T	3	91.0	83.7	81.6	87.7	87.3	85.2
2,4,5-T	4	68.8	83.3	87.4	91.0	78.5	80.0
2,4,5-T+2,4-D*	3	83.2	43.0	79.4	80.0	75.0	38.4
2,4,5-T+2,4-D	4	85.7	67.8	80.6	83.8	64.0	59.3
2,4,5-T+2,4-D	5	77.6	83.9	89.6	88.2	73.6	72.2

*Propylene and polypropylene glycol butyl ether esters.
**Pounds acid equivalent per 100 gallons of spray.

was killed. In determining this the total length of the stem was measured as well as the distance that kill had moved down from the stem apex. This distance was then calculated as a percent of the total length.

Table 2. Percent of stem-length killed and resprouting of oak from several late season sprays.

Chemical	ahg	% of distance killed	% resprouting
2,4,5-T*	3	87.0	0.0
2,4,5-T	4	83.7	0.0
2,4,5-T + 5 gal. oil/100	3	86.6	3.0
2,4,5-T +10 gal. oil/100	3	95.1	2.9
2,4,5-T +15 gal. oil/100	3	98.1	4.6
2,4,5-T +20 gal. oil/100	3	97.8	19.7
2,4,5-T+2,4-D*	4	80.2	22.2

*Propylene and polypropylene glycol butyl ether esters.

These oak sprouts appeared to respond in a normal manner following treatment with severe "burn" developing where oil was included in the spray. The following spring leaves failed to develop on the old stems of any treatment though the stems were green. The "kill" moved down the stems as the summer progressed and by fall a high percentage of these sprouts were completely dead. The experiment indicated that 2,4,5–T is effective in late season control of oak. The addition of high amounts of oil apparently increased the amount of resprouting during the year following treatment. This, of course, often happens when oil is added to the spray mixture during the regular spraying season.

These experiments serve to indicate the type of action that may be expected from late fall treatment of oak. It indicates that further research on treatment of oak and other species at this stage is desirable particularly with 2,4,5–T.

General Responses

Within a few days following standard application of these herbicides the leaves tend to droop and some twisting of small stems may

be evident. The leaves gradually turn brown and proliferation of the stems may begin. Severe proliferation is quite spectacular but while the degree to which it develops appears to be associated with the vigor of the plant it is not a dependable indication of a good final kill.

Resprouts often do not develop until the following year in northern areas. The degree of resprouting depends largely upon the species involved. In general where the tops of plants are not completely killed with one application the sprouts which develop along the stem during the year following treatment are stunted and leaf functions are not normal. This type of growth does not respond as well to foliage sprays the year following the initial treatment as normal growth and it is often desirable to defer retreatment another year. On the other hand, sprouts which develop from stumps are more nearly normal and respond well to foliage sprays.

Aerial Application

Right-of-way brush control by airplane has attained some popularity in mountainous areas and in areas which are generally inaccessible to other types of equipment. The results of this type of spraying have been somewhat varied, and in general, they have given fair top kill, at least on susceptible species, while it has been necessary to make the usual repeated applications on the resistant hardwood species. While this method provides an opportunity to chemically control woody species which would normally be cut, it is subject to a number of limitations in that application must be made when winds are relatively low, and in some areas where windy weather is the rule rather than the exception this approach has had some limitations. It is important to emphasize that any group interested in right-of-way brush control through airplane applications of herbicides should be particularly careful to choose a competent applicator who has had considerable experience in this particular application. Wherever this method of application is used, it is a highly specialized type of operation. The applicator is the key to the success of the project and he should be chosen very carefully.

BASAL SPRAYS

Basal spraying consists of spraying the basal area of the plant from the ground line up to a point a foot or a foot and a half above the ground. This application should be made in such a way that copious amounts of spray are used and they should be applied until the liquid can be seen running into the ground to the root area. In general, the spray mixture should be 16 pounds acid equivalent of 2,4,5–T ester per 100 gallons of spray solution. 2,4,5–T has generally been more effective than 2,4–D, during the dormant season and has given more consistent results than the mixtures containing 2,4–D and 2,4,5–T, although the latter have been used in some areas with considerable success. It is important to use only oil i.e., fuel oil, kerosene or diesel oil to make up the spray solutions. Spray solutions for this purpose, made up with water or varying amounts of water

have not been commercially successful and they do not appear to show any future promise for general brush control. They have, however, shown promise in the control of species which sprout from lateral structures. There has been considerable confusion on the best time to apply basal sprays and it is quite possible that there may be more variation due to the actual spraying technique than there is to the season. However, in the Southwest it is reported that basal sprays during the winter are more effective than those during the summer. In fact, application during the summer is not recommended. In the country as a whole, there are some favorite ideas on the time that basal sprays should be applied, but it is evident that any basal spray properly done will accomplish satisfactory results regardless of the time of year it is done. Basal sprays are very effective on most species, and in fact, on some resistant species as oak, maple and ash they are the most effective treatment available. However, on such typical species as sumac, elderberry, etc. which sprout profusely from lateral structures results with basal sprays are not generally satisfactory. Basal sprays on these lateral sprouting species generally give excellent top kill but do not satisfactorily suppress the development of sprouts from the lateral structures. (2)(3)(4).

STUMP SPRAYS

Stump spraying is a very effective method of controlling undesirable woody growth and the same mixture should be used for this as for the basal sprays. As with basal sprays it is highly essential to wet all exposed parts of the stump thoroughly. This includes the top, the bottom, and the exposed area of roots adjacent to the stump. Results of stump control can be improved by pushing some of the leaves and other debris away from the stump area, using the end of the spray nozzle at the time of application. This facilitates complete coverage which is necessary for complete kill. Results have been erratic on small stubs under two inches in diameter, particularly on willow.

This discussion has necessarily been very general, however, it is hoped that it may have covered one or two points that will be useful to the man in the field who is actually fighting brush, and possibly, one or two for the research man who may be undertaking work in chemical brush control. It should be emphasized that while several ways of applying 2,4–D and 2,4,5–T for the control of woody plants have been mentioned it is quite evident that no one particular method should be used in all situations. It is hoped that this discussion may have opened up a vision of a box of tools which may be drawn upon as the user sees fit, using the right tool, or combination of tools, for the right situation.

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Synthetic Plant-Growth Modifiers. IV. 2–Methyl–4–chlorophenoxyacetyl Derivatives of Amino Acids[1]

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Introduction

In the past 10 years, phenomenal advances have been made in the regulation of plant growth by organic compounds including some now used as herbicides. The introduction of new chemicals, new weed-control techniques, such as pre-emergence treatment, and low gallonage application are among the most important recent developments in the use of organic compounds for weed control. It is estimated that losses caused by weeds on farms have now reached 5 billion dollars annually, and at present well over 30 million pounds alone of the phenoxy compounds, 2,4–dichloro, 2,4,5–trichloro-, and 2–methyl–4—chlorophenoxyacetic acids (2,4–D, 2,4,5–T and MCP) are being used for herbicidal purposes to help combat these losses (9). The most recent of these three compounds to appear on the market in this country as an active ingredient in herbicidal formulations is 2–methyl–4–chlorophenoxyacetic acid. The chief claim made for its use as a herbicide is that it is less injurious to certain grasses, cereal crops and legumes and more effective on certain weeds than 2,4–D. Fertig (4) concludes that MCP is slower in action and definitely less injurious to legumes, and Crafts (3) cites a number of investigators who have shown that MCP is more selective than 2,4–D, particularly where clover, flax and other crops having leaves hard to wet are concerned. High specificity of the compound is indicated by numerous reports in the literature; Robinson's (8), on the effectiveness of MCP in selective weed control, is one example. However, from recent recommendations (1), there appears to be some disagreement on the use of MCP, indicating need for further testing and experimentation with the compound and its derivatives. MCP as sold may contain up to 40% of impurities by weight, some of which, according to Hansen (6), may have toxic properties.

Although the mode of action of the halogenated phenoxyacetic acids is not fully understood, indications of the mechanism involved when plants utilize some 2,4–D derivatives have been obtained by the synthesis and testing of a number of *D*–, *L*–, and *DL*–amino acid derivatives of these compounds. It has been reported that com-

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pounds prepared at this Laboratory (11) of the N–(2,4–dichlorophenoxyacetyl)–*L*–amino acid type appear to possess plant-growth modifying activity of the same magnitude as 2,4–dichlorophenoxyacetic acid (10,11). The *DL*–derivatives of this series are approximately one half as active as the *L*–isomers (10).

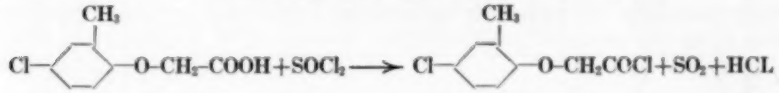
Plants affected by this type of growth-modifier appear to have cellular hydrolytic enzymes capable of splitting the amide linkage of *L*–amino acid compounds to liberate the free carboxyl group of the substituted phenoxyacetic acid which is deemed essential for activity. In the earlier investigation (11), the *D*–amino acid derivatives appeared to have little or no growth-modifying activity, suggesting that the assay plants were incapable of splitting the *D*–amide linkage; however, some of these *D*–amino acid derivatives did cause fruit to set and produced parthenocarpic fruit.

Because 2–methyl–4–chlorophenoxyacetic acid has important herbicidal properties and the amino acid derivatives of 2,4–D previously prepared (11) have been of particular value to investigators studying the mode of action of plant-growth modifiers (10), it was deemed advisable to prepare a series of MCP derivatives of the *D*–, *L*–, and *DL*–amino acid type. The new compounds prepared are listed in Table 1. Preliminary screening tests have been made, and a broad systematic herbicidal evaluation, including pre- and post-emergence tests, of the compounds is in progress.[2]

MCP Amino Acid Synthesis

The general procedure used for the preparation of the 2–methyl–4–chlorophenoxyacetyl derivatives is similar to the one described by Wood and Fontaine (11) for N–(2,4–dichlorophenoxyacetyl)–*D*–aspartic acid. The method is essentially the Schotten-Baumann reaction involving the use of the phenoxyacetyl chloride as intermediate. Modifications of the procedure are outlined under "Reaction Conditions". *Materials Used.* The 2–methyl–4–chlorophenoxyacetic acid used in this work was obtained from commercial sources[3] and further purified by recrystallization from benzene; m.p. 119°–120° C. The amino acids were the best obtainable from commercial sources and were used as received without further purification.

2–Methyl–4–chlorophenoxyacetyl chloride. This compound was prepared in 93.5% yield by the reaction of 2–methyl–4–chlorophenoxyacetic acid (I) (1 mole) with thionyl chloride (1.5 moles); the method used was essentially that described by Freed (5).



I II

[2]Herbicide tests being conducted by Dr. W. C. Shaw, Division of Weed Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Beltsville, Md.

[3]Supplied through the courtesy of Dow Chemical Company, Midland, Michigan and Monsanto Chemical Company, St. Louis, Missouri.

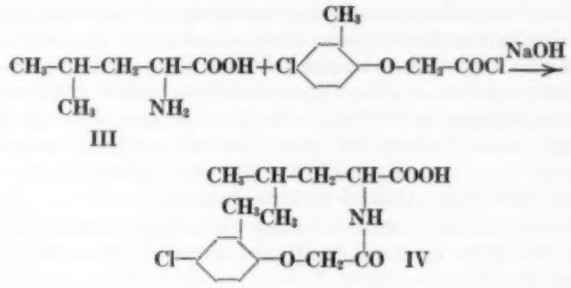
Table 1. Yields, physical properties and analyses of 2-methyl-4-chlorophenoxyacetylated amino acids.

N-(2-Methyl-4-chlorophenoxyacetyl)-	M.P., °C.[a] (Corr.)	Yield, %		Formulae	Analyses[b]					
					Cl		N		Optical rotation[c]	
		Crude	Refined		Calc'd.	Found	Calc'd.	Found	$[\alpha]_D^{25}$	Conc. (g./100 ml.) in pyridine
L-alanine	184.0–186.0	73.4	56.2	$C_{12}H_{14}ClNO_4$	13.05	13.00	5.15	5.13	+13.7±0.4	3.15
D-alanine	186.0–187.0	90.0	60.1		13.05	13.01	5.15	5.11	−13.5±0.4	3.04
DL-alanine	199.0–201.0	82.5	40.4		13.05	12.86	5.15	5.17		
L-aspartic acid	187.0–188.0[d]	56.8	34.8	$C_{12}H_{14}ClNO_6$	11.23	11.22	4.43	4.42	+42.5±0.5	2.52
D-aspartic acid	175.5–176.5	65.6	36.8		11.23	11.44	4.43	4.26	−41.2±0.5	2.63
DL-aspartic acid	203.0–205.0	37.8	22.4		11.23	11.34	4.43	4.44		
L-leucine	149.0–151.0	73.0	67.8	$C_{14}H_{18}ClNO_4$	11.30	11.31	4.46	4.44	+4.2±0.4	3.02
D-leucine	146.0–147.0	98.8	39.5		11.30	11.47	4.46	4.44	−4.3±0.4	3.10
DL-leucine	139.0–140.0	69.6	62.2		11.30	11.12	4.46	4.29		
L-methionine	123.0–124.0[e]	71.6	58.6	$C_{14}H_{18}ClNO_4S$	10.68	10.59	4.22	4.13	+10.3±0.4	3.03
D-methionine	124.0–125.0[e]	96.5	63.3		10.68	10.73	4.22	4.11	−8.6±0.4	3.12
DL-methionine	125.0–126.0	88.9	65.1		10.68	10.78	4.22	4.08		
L-phenylalanine	143.0–144.5	56.4	45.1	$C_{18}H_{18}ClNO_4$	10.19	10.25	4.03	4.08	+18.6±0.4[f]	3.02
D-phenylalanine	125.5–126.5	92.0	41.8		10.19	10.45	4.03	3.91	−24.1±0.4	3.78
DL-phenylalanine	132.0–133.0[g]	91.6	38.0		10.19	10.12	4.03	3.90		
L-threonine	108.5–110.0[h]	74.5	22.7	$C_{12}H_{16}ClNO_5$	11.75	11.57	4.64	4.53	+18.3±0.4	3.07
D-threonine	114.0–115.0[h]	70.6	26.5		11.75	11.69	4.64	4.54	−18.6±1.1	1.17
DL-threonine	144.5–145.5[i]	54.2	17.1		11.75	11.71	4.64	4.62		

[a]Recrystallized from 50% ethanol unless otherwise indicated.
[b]Analyses by M. J. Bythrow and R. B. Kelly.
[c]Optical rotations and interpretations by J. S. Ard.
[d]Required one additional recrystallization from ethyl acetate-petroleum ether.
[e]Required two additional recrystallizations, one from 25% ethanol, one from ethyl acetate-petroleum ether.
[f]Commercial *L*-phenylalanine used as an intermediate had a rotation in water of −29.2, as compared with the reported value of −34.5 (2) and of +34.5 determined for the commercial *D*-isomer used.
[g]Required two additional recrystallizations, one from 50% ethanol, one from 25% ethanol.
[h]No recrystallization from ethanol. Three from ethyl acetate-petroleum ether.
[i]Required four recrystallizations, two from 25% ethanol and two from ethyl acetate-petroleum ether.

The acid chloride (II) boiled at 70.0° C. at 0.005–0.008 mm., with constant index of refraction ($n_D^{32.8°}$) of 1.5400. It consisted of a colorless, super-cooled liquid which crystallized upon refrigeration.

N–(2–Methyl–4–chlorophenoxyacetyl)–L–leucine. The following description is included to illustrate in detail the general procedure employed in the synthesis of all the previously mentioned MCP amino acid derivatives. *L*–Leucine (III) (1.31 g., 0.010 M) was dissolved in 30 ml. of 1 *N* sodium hydroxide (0.030 M), and the mixture was chilled in an ice bath to 5° C. 2-Methyl-4-chlorophenoxyacetyl



chloride (2.15 g., 0.010 M) was dissolved in 8 ml. of benzene; the solution was chilled, and then added dropwise with mechanical stirring, over a 5 to 10-minute period, to the alkaline *L*–leucine solution (temperature maintained at 5° C.). The reaction mixture was stirred for 1 hour while it was allowed to warm up to room temperature and was then extracted once with a 40-ml. portion and three times with 10-ml. portions of ether in a separatory funnel. The ether fractions were combined and washed with 10 ml. of distilled water. The water washing of the ether fraction was added to the alkaline aqueous solution of the product. The alkaline solution was then neutralized with 1 *N* hydrochloric acid to pH 2. During the addition of hydrochloric acid a white crystalline precipitate began to appear at about pH 3.5–4. After cooling in the refrigerator for 1 hour, the N–(2–methyl–4–chlorophenoxyacetyl)–*L*–leucine (IV) was filtered off, slurried three times with water, filtered off after each slurry and finally left overnight in a vacuum desiccator, which was continuously evacuated by vacuum pump. The dried derivative was then washed three times with hot 10-ml. portions of petroleum ether (boiling range 63–70° C.). The crude yield was 2.29 g. (73.0%), m.p. 146–147° (Kofler micro melting point apparatus). The product dissolved in approximately 175 ml. of boiling 50% ethanol. After recrystallization, the yield was 2.13 g. (67.8%), m.p. 149–151°.

Reaction Conditions. The following modifications of the method of Wood and Fontaine (11) were used in the preparation of the 2–methyl–4–chlorophenoxyacetyl–amino acid derivatives:

The amino acids (0.010 to 0.020 molar) were dissolved in 3 mole-equivalents of alkali as described. Although chilling of the reaction mixture during addition of the 1 mole-equivalent of acid chlorides

was necessary, the stirring period at room temperature was reduced to 1 hour.

In all preparations except those involving threonine coupling, the crude acetylated derivatives separated as crystalline white solids. These were filtered off, washed with water, dried under vacuum at room temperature, thoroughly washed with hot petroleum ether (boiling range 63–70°C.), and recrystallized from 50% ethanol, with the exceptions noted in Table 1. All the threonine derivatives formed oils that failed to crystallize. Upon standing in the refrigerator, the oils changed to amorphous solids, which could be washed and treated in the manner described above. Each attempt to recrystallize a dried threonine derivative from ethanol-water solution resulted in formation of an oil. Crystalline products were obtained, however, from ethyl acetate-petroleum ether combinations, with ethyl acetate as the solvent and petroleum ether as the precipitant. This medium also gave a pure product with the other amino acid derivatives where difficulty was experienced in obtaining pure products by repeated recrystallizations from ethanol-water solutions.

All the dried crude products were thoroughly washed with hot petroleum ether to remove small amounts of 2–methyl–4–chlorophenoxyacetic acid.

Since the *D*– and *DL*–isomers of N–(2–methyl–4–chlorophenoxyacetyl)–aspartic acid underwent some decomposition during drying under vacuum at 50° C., all compounds were dried at room temperature to constant weight prior to chlorine and nitrogen analyses.

As shown by analysis, N–(2–methyl–4–chlorophenoxyacetyl)–*D*–methionine crystallized as a stable monohydrate. To obtain the analytical values for chlorine and nitrogen reported in Table 1, the sample was dried in a special charging tube in the manner described by Naghski et al. (7).

The "refined yield" percentage figures reported in Table 1 do not include additional quantities of products worked up from mother liquors.

Optical Rotations. In previous work with 2,4–D derivatives of amino acids (11), the rotations were determined in aqueous sodium hydroxide solution. When this medium was used for the present series of acids, the specific rotations in most cases seemed tolerably constant, but those of the N–(2–methyl–4–chlorophenoxyacetyl)–phenylalanine isomers changed drastically with concentration, and the values did not seem to be affected in the usual manner by impurities. Possibly this was caused by formation of micelles. Although such extreme effects were not observed for the other acids of this series, it did not seem advisable to use the aqueous sodium hydroxide medium. Specific rotations of the same acid were essentially constant with changing concentrations in pyridine, and the impurities in one isomer were revealed in the normal manner. Therefore, pyridine was selected as the medium for the rotation measurements reported in Table 1.

PRELIMINARY SCREENING TESTS

2–Methyl–4–chlorophenoxyacetyl derivatives of six amino acids (*D–*, *L–* and *DL–* forms), and the parent acid, were screened for plant-growth modifying properties by the following methods. Six different plants, namely, Pinto bean, Black Valentine bean, cucumber, sunflower, barley and corn were used.

Lanolin Methods:—In testing effects on bean plants, a paste was prepared by dissolving or mixing 12.5 mg. of the test compound in 0.25 gm. of Tween 20. One gm. of melted lanolin was then added and thoroughly mixed. The paste was applied as a band 3 – 5 mm. wide and about 1 mm. thick around the first internode midway between the first and second nodes of 3 young bean plants of each variety. This amounted to about 150 micrograms of the test compound per plant. At the time of treatment the plants had primary leaves about 1.25 inches in length. The trifoliate leaves were still tightly folded in the terminal buds.

In using sunflower and cucumber plants, the paste was applied as a band 2–4 mm. wide and about 1 mm. thick on the hypocotyls (immediately below the cotyledons) of 3 young cucumber plants, Arlington White Spine variety, and 3 young sunflower plants, small seeded type. At the time of treatment, both cucumber and sunflower plants had developed cotyledons that were fully almost expanded and about 1 inch in length. The first true leaves were still tightly folded in the terminal buds.

Coated Sand Method:—In using corn and barley plants, 32 mg. of the test compound was dissolved in or mixed with 0.4 ml. Tween 20; 6 ml. of 95% ethyl alcohol was added, and the mixture was stirred. Twenty grams of quartz sand were added to make a slurry, which was then dried at room temperature. Seeds of corn (U. S. 13 hybrid) and of barley (Wong) were planted separately in composted soil contained in 3-inch clay pots. Two pots of corn (4–6 seeds per pot) and two pots of barley (8–12 seeds per pot) were used in testing each compound. Two days after the seeds were planted, 5 gm. of the coated sand was sprinkled evenly over the surface of the soil in each pot. A thin layer of sifted soil was applied to hold the coated sand in place. This application rate was equivalent to 16 lbs. per acre.

At intervals of 2, 4, 6, and 14 days following treatment, the degree of growth modification induced by the various compounds was estimated and scored according to the intensity of growth responses. The following responses were taken into account: stem curvature, epinasty, formative effects, induced cellular proliferation (gall formation) and growth inhibition.

In Table 2 the scores for the 14th day's observations are recorded; to condense the data, the other scoring has been omitted. These data are representative, although they do not show the rate of response or relative progressive effectiveness of the compounds upon growth. The percentage of plants killed by the respective compounds is also listed, although such figures are not intended to reflect herbicidal potentialities of the compounds because the tests were not designed for

Table 2. Plant-growth modifying activity of 2-methyl-4-chlorophenoxyacetylated amino acids on Pinto Bean (PB), Black Valentine Bean (VB), Sunflower (S), Cucumber (C), Barley (B) and Corn (Cn).

N-(2-Methyl-4-chlorophenoxyacetyl)-	Lanolin Method[a]—14 Days After Treatment																							
	Stem curvature				Growth inhibition				Epinasty		Formative effects		Cell proliferation								Dead, %			
													First internode		Hypocotyl		Treated area							
	PB	*VB*	*S*	*C*	*PB*	*VB*	*S*	*C*	*S*	*C*	*VB*	*S*	*PB*	*VB*	*PB*	*VB*	*PB*	*VB*	*S*	*PB*	*VB*	*S*	*C*
Parent acid	+++	4+	4+	4+	++	4+	4+	4+	4+	4+	4+	4+	+++	4+	+++	4+			4+	0	100	100	100
L-alanine	+++	+++	4+	4+	++	+++	4+	4+	4+	4+	4+	4+	+++	+++	+++	+++			4+	0	50	100	100
D-alanine	+++	+++	4+	0	+	+++	4+	+	4+	+	4+	4+	+++	+++	++	+++			4+	0	33	100	0
DL-alanine	+++	+++	4+	4+	+	+++	4+	4+	4+	4+	4+	4+	+++	+++	+	+++			4+	0	66	100	100
L-aspartic acid	+	4+	4+	4+	+	4+	4+	4+	4+	4+	4+	4+		4+		4+	+++	4+	4+	0	100	100	100
D-aspartic acid	0	+	++	+++	+	+	+++	+	0	+++	0	++					+	+++	0	0	0	0	0
DL-aspartic acid	+	++	4+	+++	+	++	4+	+++	4+	+++	4+	4+					+++	+++	4+	0	0	100	0
L-leucine	+++	+++	4+	4+	++	+++	4+	4+	4+	4+	4+	4+	+++	+++	++	+++			4+	0	66	100	100
D-leucine	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0
DL-leucine	++	4+	4+	+++	+	4+	4+	+++	4+	+	4+	4+	++	4+	+	4+		4+	4+	0	100	100	0
L-methionine	+++	4+	4+	4+	++	4+	4+	4+	4+	4+	4+	4+	+++	4+	+++	4+			4+	0	100	100	100
D-methionine	+	++	+	++	+	+	+++	++	++	++	0	++					++	+++	++	0	0	0	0
DL-methionine	+++	+++	4+	+++	+	+++	4+	+++	4+	++	4+	4+	+++	+++		++			4+	0	0	100	0
L-phenylalanine	+++	+++	4+	4+	0	+++	4+	4+	4+	4+	4+	4+	+++	+++	++	+++			4+	0	66	100	100
D-phenylalanine	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0
DL-phenylalanine	+	++	4+	+++	0	++	4+	+++	4+	+	4+	4+	+	+++		+			4+	0	33	100	0
L-threonine	+++	+++	4+	4+	+	+++	4+	4+	4+	4+	4+	4+	+++	+++	+	+++			4+	0	0	100	100
D-threonine	0	++	+++	+++	0	++	+++	+	0	+++	0	++		+++			+++		+	0	0	0	0
DL-threonine	++	+++	4+	4+	+	+++	4+	4+	4+	4+	4+	4+	+++	+++	++	+++			4+	0	0	100	0

[a]See text for method; 0, no effect; +, slight effect; ++, moderate effect; +++, marked effect; 4+, response could not be recorded because of inhibited growth or death of plants. These data represent the results of one complete experiment; at a later date the screening tests were repeated with essentially the same results.

Table 2 Continued. **Plant-growth modifying activity of 2–methyl–4–chlorophenoxyacetylated amino acids on Pinto Bean (PB), Black Valentine Bean (VB), Sunflower (S), Cucumber (C), Barley (B) and Corn (Cn).**

N-(2-Methyl-4-chlorophenoxyacetyl)-	Coated Sand Method*—14 Days After Treatment					
	Stem Curvature		Growth Inhibition		Formative Effects	Cell Proliferation, Treated Area
	B	*Cn*	*B*	*Cn*	*Cn*	*Cn*
Parent acid	+++	+++	+++	+++	+++	++
L-alanine	+++	+++	+++	+++	+++	++
D-alanine	+++	++	+++	+++	++	++
DL-alanine	+++	+++	+++	+++	+++	++
L-aspartic acid	+++	++	+++	+++	++	++
D-aspartic acid	+++	++	+++	+++	++	++
DL-aspartic acid	+	++	+++	+++	++	++
L-leucine	+++	++	+++	+++	+++	++
D-leucine	+	+	+++	+++	+++	++
DL-leucine	+++	+	+++	+++	+++	++
L-methionine	+++	+++	+++	+++	+++	++
D-methionine	++	+	+++	+++	++	++
DL-methionine	++	++	+++	+++	+	++
L-phenylalanine	++	+++	+++	+++	+++	++
D-phenylalanine	+	+	+++	+++	+	++
DL-phenylalanine	++	+	+++	+++	+	++
L-threonine	+++	++	+++	+++	+++	++
D-threonine	+++	+	+++	+++	+	++
DL-threonine	+++	++	+++	+++	++	++

*See text for method; 0, no effect; +, slight effect; ++, moderate effect; +++, marked effect; 4+, response could not be recorded because of inhibited growth or death of plants. These data represent the results of one complete experiment; at a later date the screening tests were repeated with essentially the same results.

that purpose. Corn and barley plants were not killed in these tests.

The scores for the various responses to treatment with the *D*– and *L*–compounds were added, and an index value representing the percentage of maximum effectiveness based on 2, 4, 6 and 14 day observations was assigned to each compound. These index values are presented in Table 3. Index values of the *DL*–compounds have not been reported. The reason for this is that very high concentrations of each chemical were applied in order to illustrate all of the effects. At these high concentrations, the *DL*–compounds had index values comparable to the *L*–compounds.

Discussion of Results of Plant Screening Tests

Alanine Compounds:—The *D*–, *L*–, and *DL*–forms of 2–methyl–4–chlorophenoxyacetyl–alanine are about equally effective and possess moderate to strong growth-modifying properties, as shown by data in Table 2 and index values in Table 3; the *D*–alanine compound's action on cucumber is an exception to this statement. The *D*–form appears to have had little or no growth modifying effects on this plant during the 2-week observation period. The absence, or the presence of only a relatively small amount, of a hydrolytic enzyme capable of splitting the amide linkage of the *D*–amino acid deriva-

Table 3. Index values of growth-modifying properties of 2–methyl–4–chlorophenoxyacetyl derivatives of *D*– and *L*–amino acids.

Amino acid	Pinto Bean		Black Valentine Bean		Cucumber		Sunflower		Barley		Corn	
	D	L	D	L	D	L	D	L	D	L	D	L
Alanine	78*	94	94	94	5	90	67	70	42	42	93	93
Aspartic acid	44	39	33	94	62	90	52	59	33	67	60	93
Leucine	0	100	0	100	0	90	0	78	50	83	80	93
Methionine	39	100	61	100	67	90	26	56	42	42	80	93
Phenylalanine	0	72	0	100	0	90	0	67	33	42	67	93
Threonine	39	78	61	100	67	90	26	78	42	58	80	93
Parent acid	100		100		91		74		67		93	

*Index values (I.V.) represent calculated percentage of maximum effectiveness based on observed stem curvature, epinasty, cellular proliferation, formative effects and suppression of regulative growth at 2,4,6 and 14 days.

$$\text{I.V.} = \frac{\text{Summation of observed values for responses (2, 4, 6 and 14 days)} \times 100}{\text{Total number of observations (2, 4, 6 and 14 days)} \times 3 \text{ (max. rating)}}$$

tive is suggested as one of the possible reasons for this behavior. In barley, all three isomeric forms of alanine-MCP compounds seem to have somewhat limited effects on growth, with no killing action. The corn plant is somewhat more responsive to these compounds than barley; marked formative effects[4] were apparent but all plants survived the treatment. In some instances alanine compounds actually killed the plants, 100% of the sunflower and 33–50% of the Black Valentine bean; also *L*– and *DL*–alanine killed 100% of the cucumber.

Aspartic Acid, Methionine and Threonine Compounds:—All optical forms of these three amino acid compounds possess slight to marked influence upon growth responses (Tables 2 and 3). Generally, however, the *D*–isomer was not so effective as the *L*–form. In the case of the aspartic acid derivative, however, the response of the Pinto bean and sunflower to the *D*–isomer was essentially the same as that of the *L*–compound.

The Pinto bean (Table 3) gave a moderate response to *D*– and *L*–aspartic acid derivatives and the *D*–methionine and *D*–threonine derivatives. Cell proliferation occurred, however, at the area treated with both *D*–threonine–MCP compound and all forms of aspartic acid derivatives. These compounds induced a similar effect when applied to bean, sunflower and corn plants (Table 2). In general, the Black Valentine bean, the cucumber and the sunflower responded to a marked degree to the *L*–forms; all except *L*–threonine caused death of plants in every case. The *DL*–forms of aspartic acid-methionine- and threonine-MCP compounds were less effective. The *D*–forms of these three compounds never resulted in the death of any plant in the 2-week testing period. Barley was less responsive than corn to all optical forms of these three amino acid derivatives.

Leucine and Phenylalanine Compounds:—Differences in responses of plants treated with the *D*– and *L*–leucine and phenylalanine de-

[4]Unusual leaf shape.

rivatives are most striking (Table 2). The Pinto and Black Valentine beans, cucumber and sunflower showed no response to the *D*–forms of these compounds. Growth inhibition and slight stem curvature occurred in the barley and corn plants, and the *D*–compounds had formative effects on corn. The *D*–isomers, however, did not produce death of plants during the test period. In these plants the amide linkage of the *D*–amino acid derivative appeared more difficult to hydrolyze than did that of the *L*–form. Behavior of the *L*– and *DL*–forms of leucine and phenylalanine was similar to that of the other amino acid *L*– and *DL*–forms previously described.

In these tests, the amino acid-MCP derivatives have shown marked selectivity depending on the kind of amino acid, the optical isomer, and the kind of plant.

SUMMARY

A series of new 2–methyl–4–chlorophenoxyacetyl derivatives of *D*–, *L*–, and *DL*–amino acids was prepared, and the compounds were tested for plant-growth modifying activity.

In general, the derivatives of *DL*– and *L*–amino acids were active as plant-growth modifiers when tested on 6 different plants; those of *D*–amino acids were less active. The *D*–leucine and *D*–phenylalanine derivatives were inactive over the 2-week test period. Results varied in degree but were in close agreement with those previously reported for the behavior of some corresponding 2,4–dichlorophenoxyacetyl amino acids. The individual *D*–amino acid derivatives, exhibited a high degree of specificity and a wide variety and degree of activity relative to various plant responses.

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Regulatory Aspects in Weed Control*

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California Department of Agriculture

RESEARCH, education and regulatory work in the weed control field had much in common fifteen or twenty years ago. Few materials were then available for chemical weed control and a great deal of emphasis was placed on cultural methods. The regulatory man was doing extension work and the extension man in some states was doing regulatory work, assisting with or actually setting up weed districts, the overall objective, however, being control.

With the introduction of the dinitros, the hormone-like materials and others this picture has changed although the objective is the same—weed control. The men in research had and still have the most important part to play in the weed control program. They are the fact-finding group; they give extension workers, material for the educational programs and give regulatory officials information which aids them in regulating labeling provisions as well as in the use of hazardous materials which may be injurious to crops. Most important, they furnish the information needed to guide us in making the proper recommendations where abatement procedure is necessary.

With the many new developments in weed control the educational program is very important to both the men in research and in the regulatory field. Regulatory work is made simpler when the users of herbicides have an understanding of weed control and knowledge of the materials they are using. Both research and extension workers can assist greatly if they themselves understand the laws and their objectives and the men in the regulatory field can help both research and extension. Although the work in each field has expanded extensively and one must confine his thoughts to his particular field, the objective must not be forgotten. This statement is made primarily because there appears to be a trend in some areas for certain groups to become less interested, and in a few instances critical of the work of others. With a clear perspective of the job this could be avoided.

Weed control workers have a very important place in our national agricultural program and their responsibility is going to continue. The U. S. Department of Agriculture has estimated that by 1975 we will have a population of 190,000,000 people. This will require 150,000,000 additional acres of land in order to feed the population on the same standards that we now enjoy. We are several million acres short of that figure at the present time. If these estimates are correct weed control will have an important place aiding in the development of new lands and assisting with control programs for highest food production.

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*Presented before the First National Weed Control Conference at Kansas City, Missouri, December 8, 1953.

The statement has been made that insects alone take some four billion dollars annually in crops and livestock and that losses due to weeds equal that of insects, plant diseases and animal diseases, and are surpassed only by soil erosion. This presents a challenge to everyone in weed control, regardless of his special field of interest.

REGULATORY ASPECTS IN WEED CONTROL

Laws and regulations are necessary in the operation of any extensive program but only two problems dealing with this phase of the program will be discussed. The first, "pest control operators and hazardous materials" is of general interest; the second, "feed grains and screenings" also is of interest to many in the regulatory field.

Those states having extensive diversified farming have encountered some very difficult problems where susceptible crops have been injured by drift of a hazardous herbicidal material. The material causing most of the trouble is, as you all know, the hormone type of herbicide. A number of states have found it necessary to enact laws which would provide regulations to control this problem. The laws are very similar in that they are framed to control the use and application of an injurious material. Some states have broad provisions which cover all types of injurious pesticides, while others have pointed to 2,4–D and 2,4,5–T.

It is unfortunate that when state legislative bodies enact laws that they do not appropriate adequate funds to enforce the provisions. This is a common complaint from regulatory workers. Factually a law is no better than the manner in which it is enforced. After laws are enacted most state legislatures give their departments of agriculture the authority to promulgate rules and regulations. After public hearing where all interested parties may appear and have an opportunity to consider the rules and be heard, the rules are adopted. If those persons using hazardous materials follow the rules and regulations, crop damage may be prevented or at least minimized. Unfortunately some operators do not agree with these rules and it is this type of operator who causes most of the trouble.

It can readily be seen that enforcement is very difficult, especially when materials are applied by aircraft because the operator can change the pressure, volume and flight pattern that were approved for his spray operation. No state has provided funds for co-pilots.

Where rules are followed to the best of the operator's ability damage to susceptible crops is held to a minimum. Regulatory officers are not unreasonable but they must enforce the law and when there is crop damage and the operator is found to be at fault after thorough investigation the penalty is denial of permission to operate, plus a damage suit if filed. The operators who wish to stay in business are continuing their spray operations because they are following the rules and regulations which are designed to help them and keep them in business. It is not desired that any legislation be enacted that will prohibit the use of a material which has proved as valuable to the nation's agriculture as have the hormone-like herbicides. However, this has already been considered. As recently as August 3, 1953 a new

cotton organization was formed in one of the states to fight 2,4–D. The group has hired the state's best known criminal lawyer to represent them. The attorney announced that he planned to file several suits against rice growers and make a fight before the legislature to abolish the use of 2,4–D at the next regular session. The organization will be financed by an assessment of one dollar per bale of cotton. The complaints against the use of 2,4–D by rice growers came from many cotton farmers who have complained that for the last four or five years they have lost annually as high as three-fourths of their crop.

Another state has legal provisions enabling the Director of Agriculture to establish rules and regulations setting up certain areas as hazardous areas where hormone-like materials are prohibited between March 15 and October 15.

Research through the agricultural engineering divisions is giving the drift problem a great deal of attention and everyone concerned hopes that something helpful will be forthcoming in this very important problem.

The farmers losing crops surely have reason to complain. On the other hand, farmers who can not save a crop or a portion of that crop because they are deprived of the use of a material which would save it through weed control are being penalized and likewise have a complaint.

In many states where crop damage has occurred, pest control operators must take out a license which is generally granted only after examination. In some areas a permit to spray must be obtained and this permit explains the conditions under which the spraying must be done. In most cases the regulatory officials are doing all they can with their available funds to enforce the provisions under their jurisdiction.

Further research and continued education are necessary if we are to continue the use of these injurious materials near susceptible crops. This is certainly a situation where prevention through research and education is far better than an attempt to establish cause of violation and to obtain a conviction.

Other factors enter into the problem encountered by the regulatory official. One is where everything is apparently favorable for spraying—early morning low air temperatures, practically no wind, proper pressure and volume per acre, proper speed and altitude. The job may be completed with no reason to believe that there would be trouble but in due time crops were found injured by 2,4–D several miles away from the only area that had been treated in the vicinity. This situation could possibly have been caused by a layer of "stable air" which is capable of holding very small particles on the order of large molecules, up to several microns in size which may travel a considerable distance in this "stable air" before falling. If these particles are very small they can stay in the air, not falling on the adjoining crops. They may go some distance before falling. Should they fall over an area of susceptible crops injury will occur when there is a temperature inversion. The work in Mississippi

by V. H. Goodman showed that 0.001 pounds per acre of 2,4–D on seedling cotton plants caused typical symptoms; the plants recovered, however; but at the rate of 0.01 pounds per acre the crop was reduced to 68% of normal.

Small particles of 2,4–D in "stable air" have possibly caused some of the crop injuries brought to our attention.

Inasmuch as the regulatory official is called upon to investigate all types of crop damage it may be of interest to hear of another situation that for a time was difficult to understand. The crop in question was cotton in an area where 2,4–D spraying was prohibited. The symptoms were typical. The field had been treated with 2 quarts of emulsifiable DDT and 1 pint of Sistox at the rate of 5 gallons per acre. Conditions were such that applications could be made only during early morning and late afternoon of the same day.

The operator stated that early in the year he had used the airplane in applying 2,4–D in two other states, but that the equipment had been thoroughly cleaned according to prescribed methods and standard procedure and that thousands of gallons of insecticides had been applied to forest lands. Following this forest work it was again cleaned before applying the DDT to the cotton. The cleaning method used was steam with a solution of ammonia which was held in the equipment for 72 hours, then rinsed with sodium bicarbonate and clean water.

From the pattern of the contaminated cotton in the field it was evident that during the period that the spray solution remained in the nurse tank and plane between spraying operations the solvent in the emulsifiable DDT dissolved the residual 2,4–D from the equipment and contaminated the insecticide. Here again a very small amount of 2,4–D caused crop injury with further evidence that 2,4–D spray equipment should be used only for weed control. Controlling the use of hormone-like materials is a difficult but not impossible task if everyone working with them will try to understand their limitations.

The second problem, weed seed infested grain and screenings, has long contributed to the dissemination of weed seeds and regulation constitutes a very important phase of weed control. Billions of pounds of weed-infested grains and screenings are shipped throughout the country annually. These weed seeds may eventually become established and may possibly be the source of the establishment of a new weed in a given area. This, of course, has been the history of the introduction of many of our more serious perennial noxious weeds. There are very few state laws designed to handle this problem and those states that have laws find them difficult to enforce. In some instances the grain has been held for cleaning where noxious weed seeds have been found but later the screenings were permitted to move without processing to kill the weed seeds.

It is unfortunate that there are no federal requirements on grains bought and moved in inter-state commerce under governmental control. Much of this grain is infested with noxious weeds and it becomes the responsibility of the state to find the infested grain

and take action. In one instance in California where some 165 cars of grain were destined for storage until further shipping arrangements could be made quackgrass, Russian knapweed and Canada thistle were found throughout the grain. It would seem that our government could require that the grain they purchase and handle be free of noxious weeds. It seems inconsistent that one branch of our government will move noxious weeds throughout the country and other branches such as the U. S. Engineers, U. S. Bureau of Reclamation and the Bureau of Land Management will spend thousands of dollars annually for weed control.

Federal legislation for the movement of grain similar to the Federal Seed Act dealing with noxious weeds in crop seed for planting purposes would be very desirable.

This particular provision in the Federal Seed Act under Title II INTERSTATE COMMERCE reads as follows: . . . . . .

> "Kinds of noxious-weed seeds and the rate of occurrence of each, which rate shall be expressed in accordance with and shall not exceed the rate allowed for shipment, movement, or sale of such noxious-weed seeds by the law and regulations of the state into which the seed is offered for transportation or transported or in accordance with the rules and regulations of the Secretary of Agriculture, when under the provisions of section 101 (a) (9) (A) (iii) he shall determine that weeds other than those designated by state requirement are noxious"

This would be a move in the right direction in an attempt to stop dissemination of noxious weed seed in grain. Federal quarantines have no provisions which will prohibit importation of noxious-weed infested grain or screenings. The Foreign Agricultural Service has reported that during the last 11½ years 2,637,930 short tons of screenings were imported; this is approximately 220,385 tons annually. The Federal Seed Act which in this case does not prohibit entry of screenings into the United States is quoted again.

> "Section 201.223 Screenings prohibited entry. Screenings of all seed subject to the Federal Seed Act are prohibited entry into the United States *except* as provided under Section 201.224.
>
> "Section 201.224 Screenings permitted entry. Screenings of wheat, oats, rye, barley, buckwheat, field corn, sorghum including broomcorn, flax, millet, Proso, soybeans, cowpeas, field peas and field beans may be imported, provided such screenings are not imported for seeding purposes and are so declared by the words 'screenings for processing, not for seeding' in the invoice or other papers required to be presented to the collector of customs".

Nothing is mentioned of noxious weeds and it would be very helpful if, following the names of the grains the screenings of which may be permitted, there could be added "free from noxious-weed seed."

In addition to the importation of screenings, millions of tons of domestic screenings in the United States are also being moved annually. Most of this carries weed seed and much of it carries noxious-weed seed. Through the cooperation of the California Bureau of

Quarantine letters were directed to a number of other states requesting information relative to the screenings problem in their state. Fifty per cent of the replies stated that they had no provisions to control screenings in their states. From another report, the summary of laws having to do with the processing or devitalizing of screenings containing weed seed, out of 43 states only 23 have provisions either in their seed or feed laws to handle noxious-weed seed in screenings. Other states were aware of the problem and felt that something should be done. The following is quoted from a letter received from the state of Washington:

> "Screenings in general and especially so those from Canada are by far the biggest problem of the Hay and Grain and Feed & Fertilized Division. We are on the way to having a definite policy on how screenings are to be reported, transported, and treated".

Washington is taking steps to require permits and to attempt to work out a program where this particular problem can be satisfactorily handled.

Montana stated that they had no provision to control shipment of grain screenings, but did say in the closing statement of their letter that ". . . . . we would have to change the quarantine laws so that it covers this and prohibits the shipment of screenings containing weed seed . . . . . ."

Wisconsin reports in part:

> "We wish to advise that considerable numbers of carloads of grain screenings are received at Superior each year but these are all processed before being distributed to the smaller dealers and the screenings are so finely ground that there is little cause for concern from the noxious weeds that they contain in view of the fact that these weeds are already present in much larger numbers over most of the areas in which this feed is distributed.
>
> "We do not have any law prohibiting such screenings from being shipped into the state but believe there is a definite need for such legislation to protect clean farms where these weeds are kept at a minimum. It would appear inconsistent to enforce seed laws to prevent the introduction of these noxious weeds without doing something about the feed shipments which might carry similar weeds."

From Minnesota:

> "The disposition of screenings of all kinds and from all sources is a major problem confronting agriculture today. It must be recognized that there is considerable feed value in most of the screenings but at the same time they do present a menace inasmuch as considerable noxious weed seeds are spread around through the movement and feeding of such screenings."

It is recognized that there is some feed value in screenings and that there should be some means of taking advantage of this product. The National Association of Feed Control Officials has made a thorough study of the problem and the screenings committee and screenings investigators submitted a report in 1951 to their national

association. This matter has come up repeatedly at meetings of seed control officials, and feed control officials, as well as weed control officials. As yet, however, no satisfactory solution has been found, but it is certain that further attacks on this problem must be made in order to safeguard the interests of American agriculture. A great deal of credit should be given the National Association of Feed Control Officials and their committees who have been working on this problem and all people in the field of weed control should make an effort to cooperate and assist with this problem. A great deal could be done through national action and national recognition of the problem with possible consideration of legislation and uniformity among the states would be of great assistance. Through better highways and modes of travel the nation has become much smaller and the movement of such material much more rapid.

In conclusion, the regulatory officials have a big job before them and they will wholeheartedly welcome cooperation from all other agencies. I would like to emphasize again the necessity of uniformity in laws in so far as they can be carried out on a national scale.

Responsibilities of an Extension Weed Specialist*

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Weed control as we know it today is a new field with frontiers and relationships that have not been clearly charted. Weed control workers are, in a sense, pioneers. The background of knowledge is still not great and many of the questions our farmers are asking have no unequivocal answer. The sources of information are still not clearly defined and many agencies are involved in the search for information. Within any one university or college one frequently finds information that the weed specialist needs developing in the departments of botany, agronomy, vegetable crops, horticulture, chemistry and agricultural engineering. Commercial organizations of many kinds are discovering new facts that we need to know. And not the least of these sources of information is the Extension Service itself because county men, and the farmers they work with, are constantly adding to our knowledge. It is a dull man indeed who can view field after field treated to control weeds without arriving at a good working hypothesis of what *can* be done and how to go about doing it. The role of the Extension Service in the development of weed control over the past ten years has been overlooked in our emphasis on research. I would not for a moment minimize the importance of the emphasis on research but I do decry the lack of parallel emphasis on encouraging the use of the knowledge so developed. And the Extension Service in the many states has been a potent force in developing the new information credited to research.

This indicates that the job of an Extension Weed Specialist is not a cut-and-dried position, not one of performing old tasks in old ways, but a new and developing and exciting challenge. It will take the best people available to do a successful job, and many mistakes will be made as we stumble along. But there is a future in weed control, and the Extension Specialist is in the thick of it.

Now, it would be possible to discuss responsibilities from many different viewpoints. I would like to develop for you my idea of the job the Extension Weed Specialist must do within six areas of responsibility. These are, to my mind, the six jobs the Extension Weed Specialist has to do. This is in some ways a blueprint of an ideal program and certainly those of us on the job realize our limitations in one or more, or in all of the areas.

(A.) The first of these areas of responsibility is in subject-matter leadership. No extension specialist can afford to be entirely a follower waiting for programs to develop or for all the desirable research to be completed before he goes into the field. If he does he will find not only his own county people but the farmers ahead of him. His

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value to the service and to the farmers depends, in large measure, on his stature in the field of weed control.

Subject-matter leadership is, in part, the exercise of judgment in the selection and application of information. The field of weed control is so new and complex that we must choose from the available information with care, and must realize that differences of opinion and even controversy exist. The function of subject-matter leadership is one of sorting out, of selecting subject-matter, of drawing lines and of emphasizing, bringing together and adapting information into practical, usable segments. It often means searching for bits of information and piecing together what little is found, because there are never as many answers coming from research as there are questions and problems coming from the farmers. It requires a continuous study of field needs, a close relationship with subject-matter divisions and access to the information and experiences of other colleges and organizations. It takes effort to develop subject-matter leadership, and even more to maintain such a position. But the value of the specialist will depend on how well he measures up.

(B.) The second responsibility of the Extension Weed Specialist, is county staff training. The county staff is the keystone of our whole extension system. The specialist exists primarily as a source of knowledge and of help to the county people. They are the ones who contact the farmers directly and it is the job of the specialist to see that they are supplied with the latest information and with the techniques for using it. There are many ways in which this responsibility can be met—circulars, news letters, training conferences, and county visits—to mention only a few.

A knowledge of county needs and county people is required. In weed control there is a particularly difficult problem because most county people have been trained in other fields. They are agronomists, horticulturists, animal husbandmen, etc. Weed control is rarely a part of their college training and weed control is a relatively small segment of their county responsibility. It must be fitted into an already full load of other information that they must carry. And from the standpoint of the weed specialist, it means that every man in the county may have need for weed control information in his particular commodity specialty—field crops, forage crops, range, pasture, vegetable crops, tree fruits, grapes, citrus, etc. This requires a different approach from that of the agronomy specialist or the livestock specialist, who works with one or, at the least, two men in each county.

(C.) County staff training leads naturally into the third field of responsibility—that of assistance in planning county programs. It should be emphasized that the role of the specialist is *assisting the counties* to plan their own program. The responsibility for the county program belongs with the county staff. The specialist with the subject-matter background and the broader knowledge of the state as a whole is in a position to advise and to suggest, perhaps even to lead, but certainly not to drive. It is usually a question of stimulation and encouragement, although with a good county staff it may well

mean trying to keep up with demands for information in the rapidly developing field of weed control. It is intimately tied in with county staff training, since a well trained county staff will develop an adequate program.

(D.) The fourth area of responsibility of the specialist is liaison with the experiment station. This might also be called relationships with subject-matter divisions, since in most colleges and universities there are a number of divisions or departments contributing information in the field of weed control. This responsibility is a major one. The specialist has the role of a middleman, both taking out information and assisting in its application to the problems of the state and bringing information in to stimulate and guide research. The specialist is an important member of the research team. He must know the subject-matter people, their attitudes, interests, and their thinking; he must know their research problems and projects. Often the specialist must serve as a buffer between the farm groups with their many problems all deserving attention and the experiment station with limited budget and personnel to attack these problems.

The specialist has the responsibility of interpreting the work of the experiment station for the county staff and farmers and he must make the most of the opportunities to build closer acquaintanceships and working relationships between county staff and experiment station personnel. He is first of all an educator but he must understand research and the problems of research—even the limitations of research. Although his participation in research is limited, the specialist must be qualified to meet the research worker on equal terms. This aim can be furthered by participating in seminars, research meetings, and department program planning and by sharing offices with a subject-matter department. Although this latter idea is not accepted by all extension service administrators, I feel that the specialist has much to gain by being an active member of the subject-matter department. To be sure, it brings added duties and responsibilities, but the gain is well worth the effort. After all, Extension Specialists are employees of the same university and U. S. Department of Agriculture as the research people, and are responsible to the same farmers. In this area, again, subject-matter leadership is of paramount importance.

(E.) A somewhat similar but broader area of responsibility is the fifth one—relationships with related agencies. There are many groups in the field of weed control and extension specialists must keep in close touch and on good working relations with all of them. A surprisingly large number of groups outside the university, have an interest in programs on some aspect of weed or brush control. A partial list of them would include irrigation districts, drainage districts, mosquito abatement districts, public and private utilities, railroads, golf course associations, federal agencies, such as the Forest Service, Bureau of Reclamation and Soil Conservation Service, other state agencies, such as the State Department of Agriculture and the Division of Highways and many, many others. And

make no mistake about it, these groups have something to contribute to our program, just as we may hope to contribute to theirs.

Also in this group of related agencies, should be included the commercial organizations. The extension specialist needs to work closely with them. Of course, they have something to sell—but so do we—and we still have much to learn from their techniques of selling. In addition, they have the first information on new chemicals and are in a position to help us evaluate them. Their tests and trials are often just as valuable as our own. We need the extra hands and brains they provide. The commercial men were often trained in the same colleges as our own research people—in fact many of them came from the ranks of state and federal research and extension workers. They are part of the team.

In this same area, extension specialists have a responsibility in helping to train the salesmen through weed conferences and personal contact. We need to be sure, in so far as we can foresee, that the salesmen are giving the farmers the same information that our county staff is distributing. The salesmen work for us too, in extending weed control information. It is part of our job to see that it is the best information available.

(F.) The sixth field of responsibility of the weed control specialist is one common to all extension workers—selling extension. We are part of a greater overall program and we must understand how our limited program fits into the whole. As was mentioned earlier, the county workers have much broader responsibilities than weed control alone, and the farmers whom we serve have problems that include many phases of extension in addition to weed control. As representatives of the extension service we bear the responsibility of representing the extension service and generating an appreciation of the role of extension in the development of agricultural production and in rural living.

I have discussed these six responsibilities as areas rather than sharply defined duties because the job of an Extension Weed Specialist cannot be sharply defined. It depends, in part, on judgment, on the organizational framework within which he must operate, and on his own interests and abilities. Probably no two specialists do the job the same way or emphasize quite the same things. The one thing certain is that there are far too few specialists for the jobs that need to be done. We must build up enthusiasm and support for the extension phase of weed control to parallel that of the research phase. Meanwhile, being an extension weed specialist is like living in a railroad station. Whatever else it may be, it certainly is not a life of peace and quiet.

Extension Work with Respect to Weed Control

P. V. KEPNER*

THE First National Weed Control Conference can accomplish many things, not the least of which is further to dramatize the fact that weeds and their control constitute a major agricultural problem worthy of our best collective efforts and attention.

Weeds are an important national agricultural problem. They have constituted a problem facing every farmer and rancher from time immemorial. And they will continue to be a problem for all time to come. However, the extent and the intensity of the problem will depend to a great degree on the effectiveness of the work done by such groups and interests as are represented in this conference. As servants of agriculture, either directly or indirectly, a major responsibility is ours to insure that the continuing battle to keep weeds under control is reasonably well won.

The Cooperative Extension Service recognizes that we must shoulder a very significant share of this responsibility. However, our responsibility cannot be met effectively in isolation. Our contribution is dependent to a very great degree on the progress made by the research scientists, whether in the experiment stations of the Land-Grant Colleges and the Department of Agriculture, or the research laboratories of industry. And in between the research laboratory and the manufacturer of weed control materials and equipment on the one hand, and the farmers and ranchers who are destined to use these materials and equipment on the other, are a vast number of dealers and handlers who can and should play an important part in speeding progress. All of us have a responsibility to see to it that these intermediate suppliers are properly informed as to the latest proven techniques and materials adapted to specific weed control problems if they are to play their part in this common effort effectively.

This is all by way of pointing out, therefore, that even though there is and must be a degree of specialization in our collective efforts to help farmers and ranchers with their weed control problems, there must be teamwork if the most rapid progress is to be made. Each of our respective groups has a responsibility to see that our part is up in position with respect to all others. I would like to say for the Cooperative Extension Service that we want to be up with the rest of you at all times in this common effort. And may I assure you that if at any time any of you feel we are not doing our part, we would not resent a prod from you. Even more, we would appreciate greatly your counsel and advice as to how we can do a better job in our educational and demonstational efforts to encourage farmers and ranchers to utilize effectively the latest techniques and means of controlling weeds effectively and economically.

*Deputy Administrator, Federal Extension Service, U. S. Department of Agriculture, Washington, D. C. Invitation paper delivered at First National Weed Control Conference, Kansas, City, Mo., December 8, 1953.

Problems of weed control permeate much of the educational work with respect to agricultural problems carried on by the Cooperative Extension Service. No significant agricultural endeavor is entirely free of weed problems. The livestock man must contend with poisonous plants, brush, and weedy pastures and ranges. The grain grower, the cotton grower, producers of truck crops, seed crops and others must economically solve their weed problems to continue in business. And usually an adequate program to control weeds on a specific farm or in a general area demands a complex of techniques and practices rather than any one single remedy.

Hence Extension efforts to help speed up progress in economical weed control must, of necessity, be attacked on several fronts simultaneously. The direct frontal attack on a specific type of weed in a given farm or area situation, whether it be through the application of a chemical control or the use of mechanical control measures, may not be at all adequate or most economical unless it is accompanied by proper consideration of the sequence of crops grown on the land involved and related cultural practices.

Hence in conducting educational and demonstrational work with respect to the best kind of a cropping system, and associated livestock programs where appropriate, for a given farm or area, the problem of weed control is a significant factor which must be considered as a part of the total complex of problems.

When advising regarding the management of the livestock herds in many areas the need for adequate weed control must be considered in laying out a pattern of controlled grazing, in determining the effective carrying capacity of the acres involved, in determining a safe seasonal calendar of utilization, and the like. Although in such educational work weed control is only one of many significant problems receiving attention, the total amount of effort expended with respect to weed control problems and methods is considerable, although not measurable quantitatively as such.

Then of course there are organized extension programs of many types carried on with respect to the control of specific weeds or associations of weeds. These take many forms, one of the most effective being well planned and advertised demonstrations on individual farms or ranches of either cultural, mechanical, or chemical weed control measures with the usual check or control area for comparison. Frequently these specific weed control demonstrations are made a part of pasture improvement and pasture management demonstrations or special demonstrations in corn, cotton, small grains, and the like. A series of such demonstrations scattered over a county provide an excellent base for organizing educational tours where the effectiveness of particular control measures can be compared under somewhat different soil and cultural conditions, but all within a fairly uniform climate and general farming situation.

Publications, principally in leaflet form, brief but explicit, are one of the very effective means used by the extension service in acquainting farmers with the latest information relative to effective weed control methods and materials. Such publications are prepared by

experienced extension personnel within the States who know the local problems, cropping patterns and most effective and safe techniques to be employed. Such ready reference materials are distributed in many ways—by county agents with appropriate covering circular letters, passed out at appropriate meetings, to individuals in response to requests for specific information, as pick-ups in county extension offices, at dealers' establishments, and otherwise.

Likewise alert extension workers in areas where weed control problems are significant utilize the press and the radio fairly extensively in attempting to stimulate greater recognition of the importance of weed control and to provide as much information regarding effective control techniques as is feasible through the use of these media. More recently television is being used where available to show the results of specific weed control measures. Although relatively in its infancy insofar as extension use is concerned, television is proving to be a most effective means of education and certain weed control demonstrations, particularly the result phases, seem admirably suited for such use.

Recognizing the values inherent in getting farmers themselves to take the leadership in such endeavors as organized weed control efforts, extension in many States assists with organizing local weed control committees and advises with these committees regarding the program to be carried out. Extension agents also correlate their demonstrational and similar work with the work of such committees, thus presenting a united front with farmers themselves in the leadership position. Extension agents also collaborate with control officials in many areas in order that control efforts may be made more effective. At the same time control measures may be used as a vehicle for greater educational accomplishments with respect to weed control.

Of course the most effective assistance the extension service can provide in terms of immediate and tangible results is that provided through direct consultation by the extension agent with an individual farmer with respect to his particular weed control problems. However, with an average of approximately 1,100 farms per county agent, including assistant agents, it is obvious that the amount of such direct counselling service that can be provided is extremely limited. Hence of necessity greater reliance has to be placed on the group approach and indirect methods of creating an awareness of the importance of weed control, adequate knowledge as to what to do, and providing the necessary stimulus to get control measures actually applied.

Probably a general outline of the approach to weed control educational work as outlined by an individual State would best portray extension activities in this field.

In this Midwestern State about the first of the year all the latest information on weed control is brought together and summarized for distribution to county agents, vocational teachers of agriculture, dealers involved in the distribution of materials and equipment, and key farmers and leaders. This information is accompanied, of course, with as specific recommendations as it is possible for the State staff

to make in view of the varying problems and conditions involved. These recommendations are developed out of a conference of all interested technicians at the college when the latest research is reviewed and interpreted in terms of practical farm operating problems.

Subsequently a series of district training meetings are held for county agents providing an opportunity for them to be brought up to date on the latest developments and to discuss problems of application with the technicians from the college.

Afterwards a series of meetings is scheduled throughout the State, at least one in each major area. These meetings are usually sponsored by the county agents working in cooperation with implement and chemical dealers. Dealers are encouraged to attend and display materials and equipment for use in weed control. These dealers are also frequently assisted by extension workers in preparing publicity regarding the specific products they are handling, and also with preparing labels and other materials for distribution relative to herbicides and their proper use.

This is done in an attempt to keep all recommendations as nearly uniform as possible. This is quite essential since in many instances the dealer is the one who has the most effective opportunity to make recommendations to the farmer as to the use of the particular herbicide, or even the proper choice of a herbicide when more than one of approximately similar characteristics is available. Through this close collaboration with dealers there is much greater assurance that they will be conversant with the latest recommendations made by the college technicians and that farmers will be receiving more uniform counsel.

These meetings are then supplemented by on-the-farm demonstrations, selected as carefully as possible to be most effective, to demonstrate the proper application of materials. Such demonstrations are very essential since the use of chemicals in weed control is still sufficiently new and is developing so rapidly as to warrant extensive use of the demonstration method with regard to proper application techniques. Later these same demonstration areas are used to show the results obtained. Such application demonstrations also provide an opportunity to explain why a particular type of herbicide is being used, and why another would be inappropriate in view of the particular crop in which weed control was being demonstrated.

This general pattern of procedure, accompanied in all cases by individual counsel, distribution of leaflets, use of the radio and the local press and other such means is fairly typical, although probably it may represent more thorough organization of work than in many States. Naturally the pattern varies somewhat from State to State. And again I would emphasize that much weed control work is carried on by extension in the process of its educational work with respect to cropping systems, cultural practices, use of fertilizer, pasture improvement and management, and the like.

Admittedly it is difficult for us in extension to measure quantitatively the amount of extension effort being directed to a specific type

of problem when it has so many inter-relations with other extension work and related problems on the farm. Probably the best criterion we have with respect to extension efforts directed specifically to weed control problems is county agents' reports as to the number of farmers which they assisted with weed control. Even here the type and intensity of help rendered may vary widely. However, the trends indicated have considerable significance. In order to determine this trend over the past decade, we had an analysis made of the information in county agents' reports:

Farmers assisted by extension agents with weed control in crop production.

Crop	Farmers Assisted		
	1943	1948	1952
Wheat	24,192	76,612	79,611
Corn	58,449	179,906	177,496
Other cereals	31,746	136,415	133,229
Pastures	107,578	209,631	269,113
Legumes	54,211	75,511	101,759
Cotton	35,190	30,547	53,942
Tobacco	5,398	31,127	37,873
Potatoes and other vegetables	73,073	88,054	91,711
Fruit	14,322	22,802	29,332
Other crops	35,674	47,372	42,705
Total	439,833	897,977	1,016,771

It is interesting to note that the number of farmers assisted specifically with respect to weed control problems increased from approximately 440 thousand in 1943 to over a million in 1952, our latest report year. Consistently throughout the period more farmers were assisted with the control of weeds in pastures than any specific crop or group of crops. Roughly a fourth of the farmers assisted in each of the years listed in the table were assisted with weed control in pastures. The next crop, in order of descending rank, in connection with which weed control assistance was rendered in 1952, was corn, followed by other small cereals, legumes, wheat, and cotton. About the same ranking prevailed in previous years.

I do not feel that we in extension are doing all that needs to be done to assist farmers with their weed control problems. By the same token, we are not able to do as much with many other major problems as their importance warrants. However, limitations of staff and time are major inhibiting factors rather than failure to recognize the need or to have the desire to render more adequate service. Neither would I contend that there is uniformity in the degree to which weed control problems are receiving attention by extension workers throughout all States or all counties within any given State. There are too many variable factors to permit or to warrant that kind of uniformity.

In the last analysis the intensity and effectiveness of extension work on weed control now depends and will continue to depend upon the degree to which we are able to equip county extension agents to deal with this important problem. They are the ones who are called upon most frequently for advice and for specific recommendations. They

are willing and anxious to render the maximum amount of service possible. But they are not inclined to be making recommendations unless they are sure they have well proven remedies to recommend. This is particularly true with respect to advising regarding the type of herbicide to use and how to use it safely and effectively.

We believe this precaution on their part is natural and justifiable. Success or failure with a given crop may well depend upon the advice given by the agent with respect to the use of a particular weed control measure. Therefore he wants facts backed by adequate research and field testing as a basis for his recommendations. All of us have a responsibility to see to it that in our respective ways we help the county agents get these facts and understand their application. When so fortified every agent will continue to move forward as aggressively as possible with a weed control educational program.

To summarize briefly: We in extension recognize we have a big responsibility to help farmers and ranchers with their weed control problems. In meeting that responsibility we need and must have the backing of adequate and proven research. We also need and solicit the cooperation of all those in industry providing the modern materials and equipment for use in weed control. We feel that we have a reasonably good program of education and demonstration in progress. But there is still room for intensification and improvement. We would appreciate the advice, counsel and suggestions of one and all as to effective ways in which we can make improvements in our educational efforts with farmers and ranchers.

I am sure this first National Weed Control Conference will have great significance through both developing a better understanding of all the problems involved and also through making more effective the fine cooperation which has prevailed before among all the groups represented here. Of course the conferences held previously on a regional basis have made very significant contributions in this regard and will continue to do so.

Our joint slogan for the future might well be—More and more effective weed control for less and less destructive weeds.

Mode of Action of Phytotoxic Oils*

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Introduction

In areas near oil refining centers, as in most of California, petroleum oils are widely used in agriculture. Reference is not made here to the use of petroleum to power and lubricate tractors and other farm machinery, but to its use as an agricultural chemical. There are three typical uses of oils: (1) insecticidal spray oils, (2) various oils as selective and general herbicides, and (3) solvent type oils as carriers for oil soluble agricultural chemicals. In California alone, annually from five to fifteen million gallons of petroleum oil are used for the control of scale, mites, and mealy bug (23). An estimated 10 million gallons of cracked gas oils are used for general weed control on canal banks, road sides, barnyards, and in orchards practicing non-tillage. Much solvent type oil is also used for selective weed control in umbelliferous crops, and for pre-emergence weed control in lettuce, beets, and onions. One large operator alone is using one million gallons annually. Aromatic fractions and fortified heavier oils are used as drying agents on flax, clover, and alfalfa seed crops and as cotton defoliants. DDT and other insecticides are commonly applied as dilute oil emulsions.

Principal reasons for the use of oils as herbicides are that they are especially suitable for the elimination of weedy grasses (4), and that when properly applied, they do not harm crop plants by toxic residues in the soil.

Previous to 1930, no special weed oils were made, unaltered diesel and smudge oil were used (23). When the diesel oils were improved as fuel by additional refining, they became less suitable as herbicides (5). At present weed oils are special oils selected to serve the purpose for which they are intended. However, it must be remembered that these special oils are not by-products in the sense that they are waste products without other uses, but are made available only in lieu of their use as fuel oil and solvents. Therefore, the availability of weed oils is inversely related to the demand for fuel oils and commercial solvents but the price relationship is normally a direct one. Distance from the source of supply also is an important factor because of shipping costs.

Penetration of Oil into the Plant

Oils wet plant surfaces readily and tend to spread as thin films. They penetrate the crown of grasses where the growing tissues are located (4). Only liquids of very low surface tension penetrate pores of

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**The collaboration of Dr. F. M. Fowkes of the Surface Chemistry Laboratory of Shell Development Company is gratefully acknowledged.

the size of stomata (11). Aqueous solutions do not, but the lower viscosity oils do penetrate the stomata. Stomatal penetration of oils has been considered the principal path of entrance of oils into leaves as early as 1903 (24). Recently, this concept has received further confirmation (19, 20, 6). Although stomatal penetration of oils is probably the main mechanism, interstomatal penetration of the epidermis is possible in tender leaves (base of grasses). On the other hand, in plants with a tough continuous waxy cuticle, such as the upper leaf surface of the apricot, cuticular penetration of unfortified oils is virtually nonexistant.

Stomatal penetration can be demonstrated readily. When an emulsion of a light oil is sprayed on young plants in the light when the stomata are open, the plant is killed. However when the same emulsion is applied during the night when the stomata are closed, the plant remains entirely unharmed. Since killing of young grass plants can take place when oils creep down the stem into the tender regions of cell growth, grasses can be killed without stomatal penetration. It was shown in a small experiment that grasses could be removed from beans by spraying of a dilute emulsion of a light oil during the time the stomata of the bean were closed.

Just as oil spreads on the external surfaces, so it spreads through the intercellular spaces. Minshall (19, 20) demonstrated that in dandelion plants as well as in carrots, oils spread from the leaves to the roots. The intercellular movement is not polar because when a cut is made in the root and oil is applied to it, it moves up into the leaves. It is generally conceded that bulk oil does not move into living cells (20, 13). Only after cells are injured can oils penetrate.

Action of oil on cells

Oils contain four types of hydrocarbon molecules: paraffins, naphthenes (saturated carbon rings), olefins, and aromatics. By spraying pure hydrocarbons on plants, Havis (13) showed that aromatics rank highest in toxicity, naphthenes and olefins come next, while straight paraffins were found least toxic. This has been known in practice for a long time, and UR (unsulfonated residue, a measure for saturated compounds in the oil) has become a standard for predicting phytotoxic properties of oils (5, 9). Havis plotted oil toxicity against boiling range and showed that lower boiling compounds appear to be nontoxic. This was due in part to evaporation of the material between nozzle and leaf surface and evaporation from the material after it had been deposited on the leaf. It is clear, therefore, that even though information obtained from spray tests has a high practical value, the fact that evaporation losses occur renders such data unsuitable for the study of the action of hydrocarbons on cells.

For these reasons, Currier (6) applied benzene and 3 methylated benzenes in a gas chamber for periods as short as 15 minutes. They were found to be of a high order of toxicity. Currier gives a description of the symptoms of the action of these compounds, which will be quoted because it is characteristic of the symptoms generally caused by oils, and by many materials dissolved in oils which produce

acute toxicity. Later, it will also be shown that at least the *first phase* of chronic toxicity is in principle identical to that of acute toxicity.

"All four compounds (benzene and 3 methylated derivatives) entered the plants rapidly (through the stomata). The first noticeable symptom was a darkening of the tips of the youngest leaves, due presumably to a leakage of sap into intercellular spaces. The darkening spread to the older leaves; there was a loss of turgor, with drooping of stems and leaves . . . the plants exhibited strong odors similar to macerated tissues. In bright sunlight chlorophyll was destroyed, sometimes resulting in complete bleaching of the dead portions."

He concludes that the most definite gross reaction displayed by

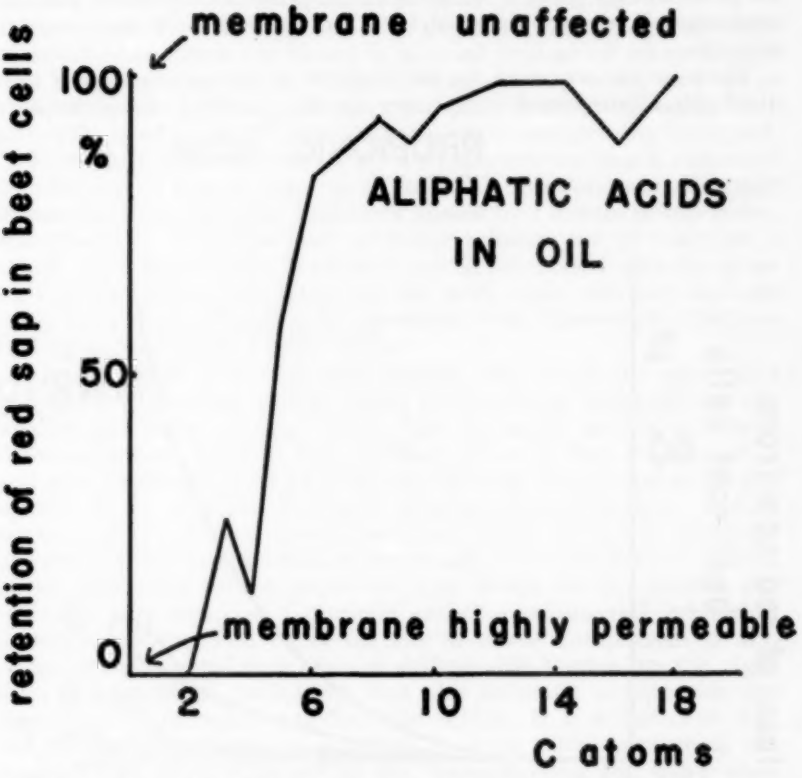

FIG. 1. Effect of molecular size of straight-chain saturated fatty acids on the permeability of the plasma membrane of beet root cells. The passage of red anthocyanin pigment to the external solution is a measure of the permeability of the membrane. Thin slices of the beet tissue were placed for 2 minutes into a 3% solution of the acids in carrot weed oil (in itself ineffective), rinsed, and then placed for 45 minutes in a buffer solution (pH 6.2). The data show that the smaller the molecules the more they tend to increase the permeability of the plasma membrane.

treated plants is an early and marked increase in permeability of the plasma membrane.

At the Shell Agricultural Laboratory, the problem of oil action has been under investigation for several years. The tests performed included several with isolated tissues. These led to conclusions similar to those reached by Currier, that in acute oil toxicity, an increased permeability of the plasma membrane is involved. However, the use of isolated tissues permitted a more quantitative treatment, which enabled us to draw a parallel between effects of hydrocarbons on plant cells and known effects of these materials on colloidal micelles.

When discs are cut from the roots of the table beet and washed in running tap water, a group of isolated cells is obtained quite suited for permeability studies. An increase in permeability of the plasma membrane is at once detected by a red coloration of the external solution.

The beet test was used for the analysis of the toxic action of oxidized oils. Crafts found many years ago that purified oils increase in

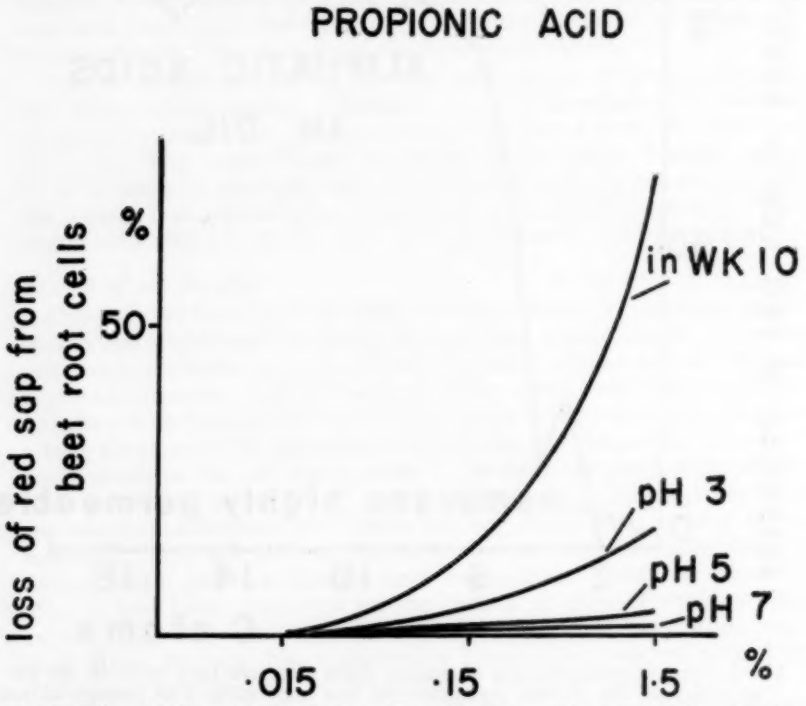

FIG. 2. Effect of dissociation of the acid molecule on the permeability of the plasma membrane of beet root cells. Propionic acid in oil (WK10, itself nearly ineffective at the 2 minute exposure) is entirely in the molecular form. In aqueous solutions the acid is progressively more dissociated with increasing pH. The data show that the undissociated molecule is responsible for the increased permeability of the plasma membrane.

toxicity when exposed to light. Havis (13) pointed out that especially olefins could be activated in this fashion. DeOng (10) described the effect of such oxidized oils, while Johnson (14, 15) proved that the toxic effect was due largely to acid formation. It was shown also by our tests that oil toxicity to beet cells can be greatly increased by oxidation. Washing the oxidized oil with alkaline water removes the acids and reduces the toxicity of the oil to its original level.

If aliphatic acids are dissolved in the (nonoxidized) oil, the toxicity is greatly enhanced, as could be expected. Interestingly, the toxicity is greatest when the molecular weight of the acids is lowest (Fig. 1). It may come as a surprise that acids such as acetic acid and propionic acid are so highly toxic. However, they display this action only in the undissociated form. The highest activity is thus found in oil, and in aqueous solutions only at a low pH (Fig. 2).

Beet tissue is relatively insensitive to pure hydrocarbons. A much more sensitive tissue was found in isolated sections of maize coleoptiles and of pea epicotyls. These sections take up water as long as semipermeability of the plasma membrane is retained, while they fail to do so when membrane permeability is considerably increased. Differences in water uptake between treatments was much enhanced by addition of 1 ppm indoleacetic acid. The sections were dipped† in pure hydrocarbons for 2 minutes, rinsed by a stream of tap water, and placed in a shallow layer of buffer solution for 16 hours on a shaker. The results (Fig. 3) showed that in agreement with the spray tests of Havis (13), aromatics are the most toxic and paraffins the least. They showed further, in agreement with Currier (6), that low boiling aromatics are highly toxic.

The new facts that these tests yielded, and which the spray data had failed to uncover, is that within each series of hydrocarbons the smaller molecules are more toxic than the larger molecules. There is no optimum. Thus in the paraffinic series of Fig. 3 octane (C_8) and also decane (C_{10}) are so toxic that they do not permit any water uptake by the sections. Dodecane (C_{12}) is nearly non-toxic, and so are the higher paraffins. The curve for the olefin series is in principle not much different from that of the paraffins, except that it is shifted to the right, indicating a greater toxicity. While the C_{12} paraffin was virtually non-toxic, the C_{12} olefin causes a substantial inhibition in water uptake. The curve for the aromatic compounds is also of the same general type, but is shifted still farther to the right than the paraffins, indicating that the aromatic compounds are more toxic than either paraffins and olefins. It is self-evident that no absolute value can be attached to these data, because if the sections had been exposed to the hydrocarbons for more than 2 minutes, the curves would have been shifted to the right. The general conclusion to be drawn from the data of Fig. 3 must there-

†For this type of study dipping the tissue in undiluted liquid hydrocarbon has many advantages over methods that involve spraying or the use of diluents. It avoids errors due to loss by evaporation, errors due to so-called "nonphytotoxic" diluents, and errors due to saturation effects (Ferguson principle) in either air or water.

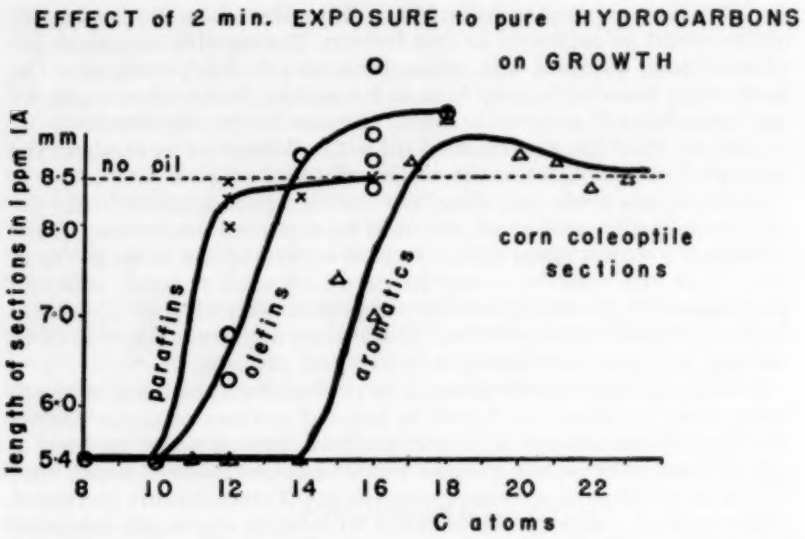

FIG. 3. Effect of pure hydrocarbons on the water permeability of the plasma membrane of coleoptile cells. Water uptake by the cells, as reflected in increased length, served as a measure of the condition of the plasma membrane. The semi-permeability of the membrane is considered destroyed when no increase in length took place beyond the original 5.4 mm; while permeability was considered normal when the sections increased to 8.5 mm. The maize coleoptile sections were dipped for 2 minutes in the oils, rinsed in a stream of tap water, then placed for 16 hours in a growth promoting solution. The data are interpreted to mean that the smaller the hydrocarbon molecules, the more they tend to increase the permeability of the plasma membrane. Note that as a class, aromatic hydrocarbons are more effective than olefins, and that paraffins are least effective.

fore be, as with the acids in the beet test, that the hydrocarbons of smaller molecular weight disrupt the plasma membrane more severely than hydrocarbons of larger molecular weight.

Before discussing the theoretical consequences of this conclusion, it should be noted that there occurred an increase in water uptake of the sections by the olefins, and also by the aromatics, of a molecular size just larger than those causing toxicity. This may be due to a slight increase in permeability of the plasma membrane, small enough to prevent sugars and other large molecules from leaving the cells, but large enough to increase the uptake of water through the membrane. The phenomenon cannot be caused by increased uptake of indoleacetic acid, because it occurred also in corn coleoptile sections and carrot root discs to which no indoleacetic acid was added.

Theory of oil action

At the turn of the century, Overton (21) from numerous experiments on plant and animal cells came to the conclusion that the plasma membrane of cells is of a fatty nature. Recently, Danielli (8)

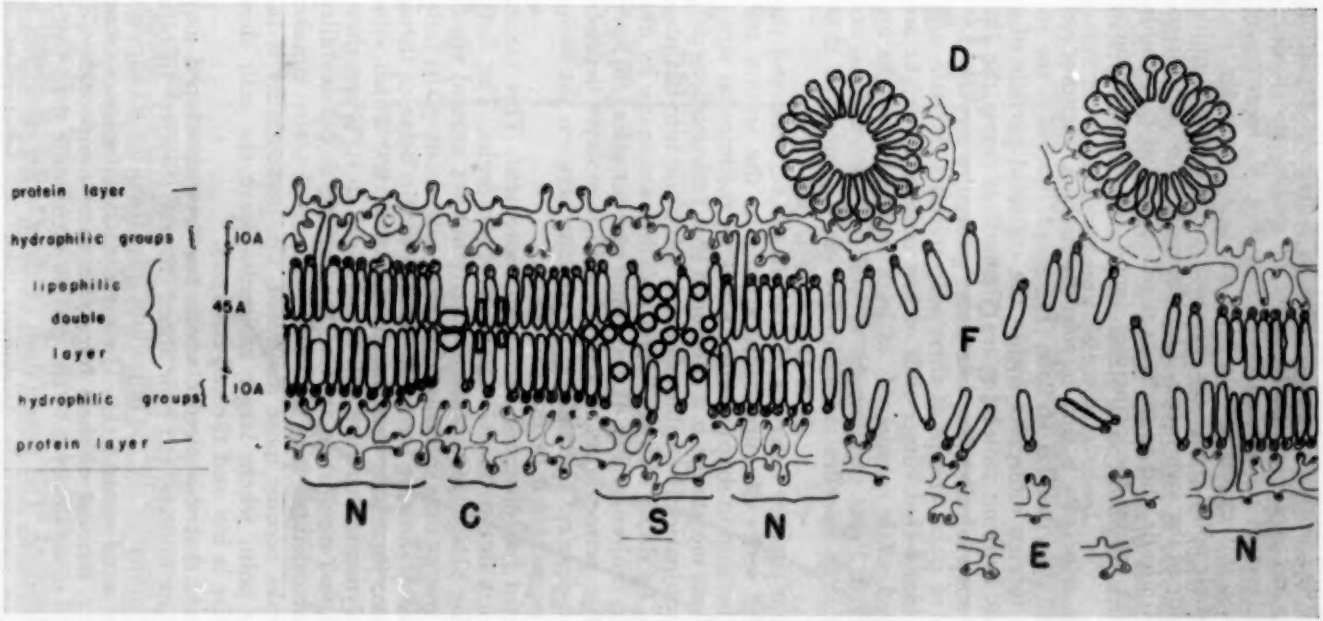

FIG. 4. Schematic representation of the plasma membrane as affected by various toxic molecules. The normal unaltered membrane (N) consists of a double layer of fatty molecules stabilized by protein layers. Materials essential to life are kept inside the cell by the central fatty portion of the plasma membrane. Increasing the spacing between the individual units of this fatty layer leads to increased permeability, which, when severe enough, causes vital materials to leak out of the cell, causing death. At S molecules such as xylene are seen solubilized into the fatty layer and at C the natural units are being pushed apart by polycyclic hydrocarbons. Detergent micelles at D are shown pulling away the protein layer, thereby rendering the fatty layer unstable (F). At E a similar disruption of the protein layer is brought about by agents which liquify the protein. Although this drawing might give the impression that the molecular arrangement in the plasma membrane is static, it must be remembered that in reality, all molecules are in a state of vigorous thermal agitation.

has summarized the work of half a century by a diagram depicting the cell membrane as a bimolecular layer of amphipatic lipoids, stabilized by a layer of protein on both sides (Fig. 4). In terms of actual molecules, this means sterols, fatty acids, triglycerides, etc., lined up with their polar groups on the outside and their lipophilic tails on the inside of the membrane. The plasma membrane is therefore a colloidal micelle and as such, its reaction toward fat soluble materials should follow the principles found for other colloidal micelles.

One of these principles is that of solubilization, a phenomenon investigated and described by McBain (17). Solubilization is the incorporation of foreign molecules within the colloidal particle of a detergent. Thus benzene molecules are "bound" between the lipophilic tails of soap micelles, just like water molecules are "bound" between layers of polar groups of these soap micelles. McBain and Richards (18) found that compounds of low molecular weight are freely solubilized while compounds of high molecular weight are poorly solubilized. Polar compounds, as well as hydrocarbons, are solubilized. In soap micelles aromatics are more solubilized than paraffins.

It will be clear that the behavior of acids in the beet test and the behavior of the series of pure hydrocarbons in the section test parallel solubilization in soap micelles. Knowing the micellar structure of the plasma membrane it is concluded that hydrocarbons and a variety of amphipatic oil soluble materials solubilize into the plasma membrane. By doing so, they "open up" the membrane by displacing the fatty molecules (Fig. 4). Langmuir and Schaefer (16) have shown that water permeability of a stearic acid monolayer depends greatly upon its density. The tighter the packing between the molecules, the less permeable it becomes to water.

Every biologist has observed Brownian movement. This rather violent motion is due to kinetic agitation of molecules. The fatty molecules in the plasma membrane similarly bounce around vigorously. Kinetic energy thus interrupts the close alignment of the fatty molecules, thereby allowing foreign molecules to slip between them. It would appear, therefore, that any foreign molecule which solubilizes in this dynamic structure will cause a leak in it. When these leaks in the plasma membrane are few, the increase in permeability under certain conditions may result in stimulated water uptake. When these leaks become more abundant, the permeability is increased to the point where larger molecules leave the cell; thus semipermeability is lost and the cell collapses.

It may be said that this picture which has been developed may account for acute toxicity, but how about chronic toxicity? In oils, the polycyclic aromatics are the important ones from the standpoint of nonselective weed control (1). These polycyclic aromatics cause chronic toxicity. Because of their large size, these compounds will penetrate much more slowly into the plasma membrane than molecules such as benzene. The penetration of these larger molecules is also much more temperature dependent than the penetration of

small molecules, as Danielli has shown. These larger molecules, however, will eventually reach the plasma membrane where they will displace the normal units of the membrane. Because of their large size, they will cause more displacement than smaller molecules as Clowes (2) could show in cholesterol films. Their fluorescence is also a factor that should not be overlooked in accounting for their great biocidal activity. However, the first steps leading to chronic toxicity are undoubtedly similar to those leading to acute oil toxicity, except that a different time factor is involved.

One might want to know how materials, as highly insoluble in

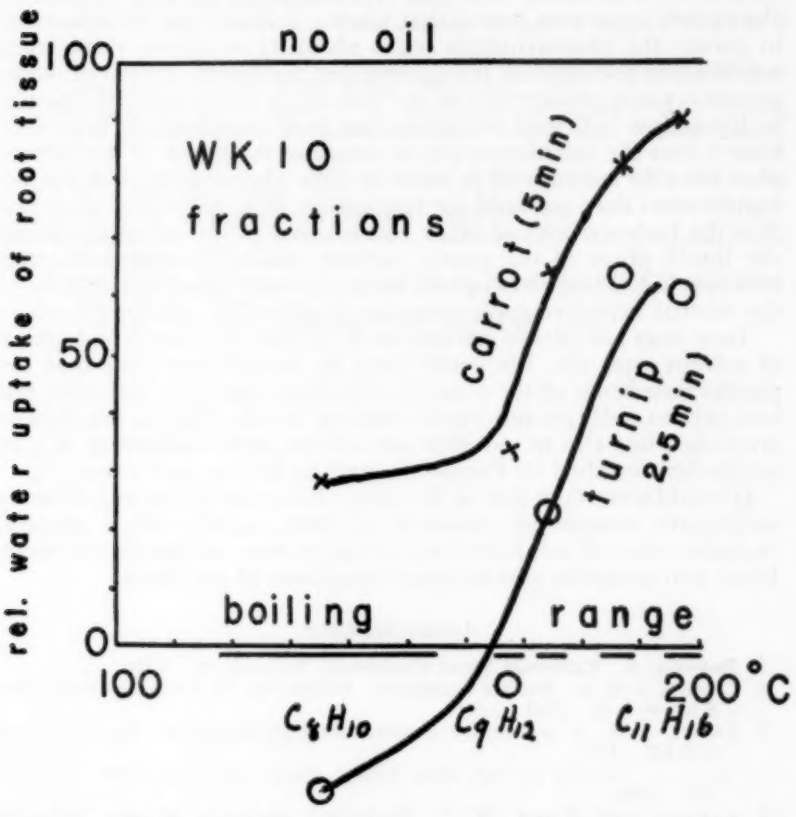

FIG. 5. Effect of fractions of carrot weed oil—whose boiling ranges are indicated by the interrupted lines below the abscissa—on the permeability of the plasma membrane of carrot and turnip root cells. Water uptake by the tissue served as a measure for the condition of the plasma membrane; a reduced water uptake reflects a reduced semi-permeability because of damage to the membrane. Thin slices of the root tissue were dipped in the oils as indicated in the graph, after which they were allowed to take up water for 24 hours. The data are interpreted to mean that the smaller the hydrocarbon molecules are, the more they tend to increase the permeability of the plasma membrane. Note that the carrot tissue is more resistant than turnip tissue to all the fractions.

water as polycyclic hydrocarbons, are capable of passing from cell to cell through the hydrophilic cell wall in order to reach the plasma membrane. It is likely that in addition to passing through the water phase, these materials move through the plasmodesmata. How many of these minute protoplasmic strands traverse the cell wall was demonstrated by Crafts (3) and again recently in the excellent electron microscope photographs of Roelofsen and Houwink (22).

One might further ask, does the solubility theory explain the drop in photosynthetic activity following oil penetration? DeOng, as early as 1928 (9), found that starch formation stops as a result of oil treatment of leaves. Minshall (19, 20), using a sensitive infrared absorption apparatus, found that when a solvent type oil is applied to plants, the photosynthesis ceases abruptly while the respiration was initially not affected. It is known that the lipoid content of chloroplasts is vastly greater than in the rest of the cytoplasm (12). Hence, hydrocarbons will tend to accumulate in chloroplasts. It is further known that the submicroscopic structure of the grana of the chloroplast must be maintained in order to have photosynthesis. A similar requirement does not hold for respiration. It is, therefore, proposed that the hydrocarbons or other constituents of the oil solubilize in the lipoid phase of the grana, thereby causing increased distance between individual chlorophyll molecules and other disruptions of the normal submicroscopic structure required for photosynthesis.

Time does not permit discussion of the selective herbicidal action of solvent type oils. We could show by further test data that the plasma membrane of the cells of umbellifers (not only leaf cells, but root cells as well) are inherently resistant to oils (Fig. 5), not only to aromatics, but also to paraffins and olefins, thus confirming in part conclusions reached by Currier (6) and by Dallyn and Sweet (7).

It would seem then that in the plant the action of oils and of many amphipatic compounds dissolved in them, is primarily a physical chemical effect of solubilization, acting at least on the plasma membrane and probably also on other lipophases of the plant.

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Weed Control in Onions in the Organic Soil of the Florida Everglades

V. L. Guzman and E. A. Wolf*

Trials at the Everglades Experiment Station have shown that onions may be successfully grown in this area. The rich organic soil and the relatively long growing season of the crop present, however, a difficult problem in regard to the control of weeds. Weeds are very numerous and their rate of growth is exceedingly rapid. The problem is of such magnitude that the expense of hand weeding in closely spaced row crops discourages the farmer from undertaking the production of an otherwise potentially profitable crop. This study was undertaken to investigate the possibilities of weed control in onions in the organic soil of the Everglades using herbicides as both pre- and post-emergence treatments and determining their effects on yields.

Pre-emergence weed control of onions in organic soil has been successfully accomplished in other areas by the use of 3-(para-chlorophenyl)-1,1-dimethyl urea (CMU) (3, 6, 11), isopropyl 3-chlorophenyl carbamate (Chloro IPC) (6, 11), 2,4–D amine (8, 11), Stoddard's solvent (11), and sodium isopropyl xanthate (NIX) (11). Some of these herbicides reduced the stand of the onion plants. This may or may not have decreased yields. Experience elsewhere has shown that sulphuric acid can be used in certain late varieties of onions for post-emergence control of weeds without reduction in yields. Good control of weeds has also been reported by the use of post-emergence applications of sulphuric acid (1, 8, 9), potassium cyanate (KCNO) (1, 2, 4, 7, 9), NIX (1, 5, 9), CMU (4, 7), disodium 3,6-endoxohexahydro phthalate (Endothal 3003) (4, 5), Chloro IPC (5, 7, 10), and Endothal plus Chloro IPC (7). In many instances reduction of stand of onion plants occurred. Evidence indicates that pre- and post-emergence weeding of onions might be accomplished successfully.

Methods of Procedure

Three experiments were conducted on a mature Everglades peat soil having a pH of 5.5, using the Texas Early Grano variety. Post-emergence experiment 1 was seeded on November 14, 1952. Post-emergence experiment 2 and a pre-emergence experiment were seeded on December 26, 1952. Randomized block designs with six replications were employed, using split plots for the pre-emergence experiment in which the subtreatments were two concentrations of chemicals. In the check plots of the pre-emergence experiment the two sub-checks were: one without cultivation except for one pulling of the weeds when they reached large size to prevent shading effect

*University of Florida, Everglades Experiment Station, Belle Glade, Florida. This work was made possible in part by grants from Columbia Southern Chemical Corporation and B. F. Goodrich Chemical Company. Florida Agricultural Experiment Station Journal Series, No. 242.

on adjacent plots, and the other was hand weeded. The three depths of seeding (½, 1, and 1½ inches) were made in order to measure any possible interaction that might exist between the depth of seeding and the effect of the herbicide on stand of the onion plant.

Chemical treatments were applied as spray at a pressure of 25 p.s.i. except for the NIX treatments which were applied at 40 p.s.i. pressure. The ground was rolled immediately after seeding with a heavy roller and the pre-emergence treatments were applied six days after seeding. After the residual effect of the herbicides disappeared from the ground, hand weeding (pulling of weeds) was necessary to keep the plots clean. The number of hand weedings varied from one to three depending on the residual effect of the chemical used. The post-emergence treatments were applied as foliage spray over the onion plants and weeds approximately 43 days after seeding. The second and third post emergence treatments were spot treatments directed as much as possible to the weeds and applied at approximately 20 day intervals. One hand weeding (pulling of large weeds)

Table 1. Pre- and post-emergence herbicidal treatment of Texas Early Grano onions in three experiments.

Treatments	Amount of active ingredient/A.	Gallons per acre
Pre-emergence Experiment		
1. a—2,4-D amine salt	1.0 pound	30
b—2,4-D amine salt	2.0 pounds	30
2. a—DNOSBP	1.5 pounds	30
b—DNOSBP	3.0 pounds	30
3. a—NIX plus wetting agent	10 pounds	90
b—NIX plus wetting agent	12 pounds	90
4. a—Diesel oil	30 gal.	30
b—Diesel oil	60 gal.	60
5. a—Stoddard solvent	30 gal.	30
b—Stoddard solvent	60 gal.	60
6. a—Chloro IPC	10 pounds	30
b—Chloro IPC	12 pounds	30
7. a—Oktone	2.5 pounds	30**
b—Oktone	5.0 pounds	30**
8. a—Check (not cultivated)		
b—Check (hand cultivated and weeded)		
Post-emergence Experiment 1		
1. Sulphuric acid	2.5% (volume)	90
2. KCNO*	12.0 pounds	90
3. NIX	10.0 pounds	90
4. Check (hand cultivated and weeded)		
Post-emergence Experiment 2		
1. KCNO*	12.0 pounds	60
2. Sulphuric acid	2.5% (by volume)	90
3. Sinox W	0.75 pounds	30
4. NIX	10.0 pounds	90
5. Chloro IPC	8.0 pounds	30
6. CMU*	2.0 pounds	30
7. Endothal 3003	6.0 pounds	30
8. Chloro IPC plus KCNO	4.0 and 10.0 pounds	30
9. Check (hand cultivated and weeded)	—	—

*Technical.
**Diesel oil.

was necessary a month after the last post-emergence application of the herbicides.

The treatments for the three experiments are given in Table 1. The KCNO and NIX treatments for both post-emergence experiments were the same in amount of active ingredients, but the amount of water used was different in the case of potassium cyanate.

Weed counts for the pre-emergence experiment were taken in one square foot areas at random at the time when the average effect of the herbicides began to disappear. No weed counts were obtained in the post-emergence experiments, since the effect of the herbicides was about equally good for all of the chemicals.

The bulbs were stored about one and a half months following harvest to determine whether there was any effect on keeping quality due to herbicidal treatment.

RESULTS AND DISCUSSION

Pre-emergence experiment—There were no visible symtoms of injury to the onion plants due to pre-emergence application of the amounts and kind of herbicides, except perhaps for a very light and temporary flattened condition in the 2,4–D treatments. Table 2 shows the yields of marketable onion bulbs in relation to treatments and the corresponding total number of weeds per square foot sample taken at random in the twelve sub-plots of each major treatment. There were no differences in yields between the chemical treatments and the check when considering the yields of the uncultivated and

Table 2. Total yield in pounds of marketable onion bulbs and number of weeds in relation to pre-emergence chemical weed control treatments.

Kind of plant	Treatments							
	2,4-D	NIX	Diesel oil	Stoddard solvent	Chloro IPC	Oktone	Check	L.S.D. 5%
Onions...	799	764	743	622	803	746	800	N.S.
Weeds....	34	77	95	110	17	45	203*	42

*Number of weeds before cultivation of the check plots is significantly more than any of the herbicidal treatments. Also the number of weeds in the 2,4-D and Chloro IPC plots are significantly less than in the rest of the herbicidal treatments except in the case of Oktone.

hand weeded plots together. There is, however, a tendency to lower yields for the relatively poor herbicides such as Stoddard solvent. This condition is probably due to an early harmful weed competition to the onion plants. Differences in yields due to concentration of herbicides applied were not significant. There is a significant reduction of weeds in the herbicide treated plots when compared with the check. The two best herbicides, Chloro IPC and 2,4–D, produced a significant reduction in the number of weeds as compared with the other treatments, except in the case of Oktone. Moreover in the case of Chloro IPC the toxic residual effect against weeds remained for slightly more than three months.

Table 3 shows the yields of plots treated with the highest concentration of each herbicide in comparison with the cultivated

check. The cultivated check produced significantly greater yields than any of the chemical treatments. This reduction in yield is perhaps partly due to the effect of the herbicides on stand of the onion plants. The fact that reduction in yield occurred in all the chemical treatments is not necessarily an indication that chemical weed control of onions might not be feasible. Hand weeding costs may be sufficiently high to offset the reduction in yield due to chemical weeding. Also, the tendency toward reduced stands might be offset by heavier seeding rates.

Table 3. Total yields in pounds of marketable onions from the highest rates† of each treatment applied in the pre-emergence experiment.

2,4-D	NIX	Diesel oil	Stoddard solvent	CIPC	Oktone	Check	L.S.D. 5%
401	386	392	321	395	376	521**	106

†The highest rates gave the best weed control.
**Yields from all treatments are significantly less than from the hand weeded check.

All plots except the check were left undisturbed until the weed growth was sufficient to estimate the residual toxicity of the herbicidal treatments. Under the conditions of this experiment the most lasting and best control was obtained with Chloro IPC followed by 2,4–D. Stoddard solvent was the least effective in controlling weeds, followed closely by the diesel oil treatment. This, of course, was to be expected since both oils are only contact herbicides. Oktone suppressed weed growth fairly well, but its effect disappeared much more rapidly when compared with Chloro IPC and 2,4–D. The effect of NIX on weeds was intermediate between that of Oktone and diesel oil. DNOSBP at the concentrations used caused death of the seedlings before emergence from the ground.

From the viewpoint of weed control with no visible damage to the plants, Chloro IPC was obviously the best herbicide (Fig. 1), followed by 2,4–D. The tolerance of the onions to the concentration of Chloro IPC and the excellent residual toxicity to weeds for over three months make the results rather spectacular; furthermore, until harvest time, only one weeding (pulling of weeds) was required on the Chloro IPC treated plots. The same was true with 2,4–D, although the residual toxicity lasted only 2 months and two hand weedings were necessary. All other treatments received three hand weedings. At the end of the growing season annual grasses over the entire experimental field interfered somewhat with the harvesting operations.

Average temperature on the date of the chemical treatments was 54°F., and for the next month and a half was below 70°F., with few exceptions. Three-fourths of an inch of rain fell between the time of seeding and the application of the herbicides. During the first month after seeding, 2.77 inches of rain fell. In the second month, 1.63 inches fell. Relatively low temperatures and also a fair amount of moisture in the upper layer of soil seem to enhance the toxic properties of Chloro IPC. These climatic conditions might to

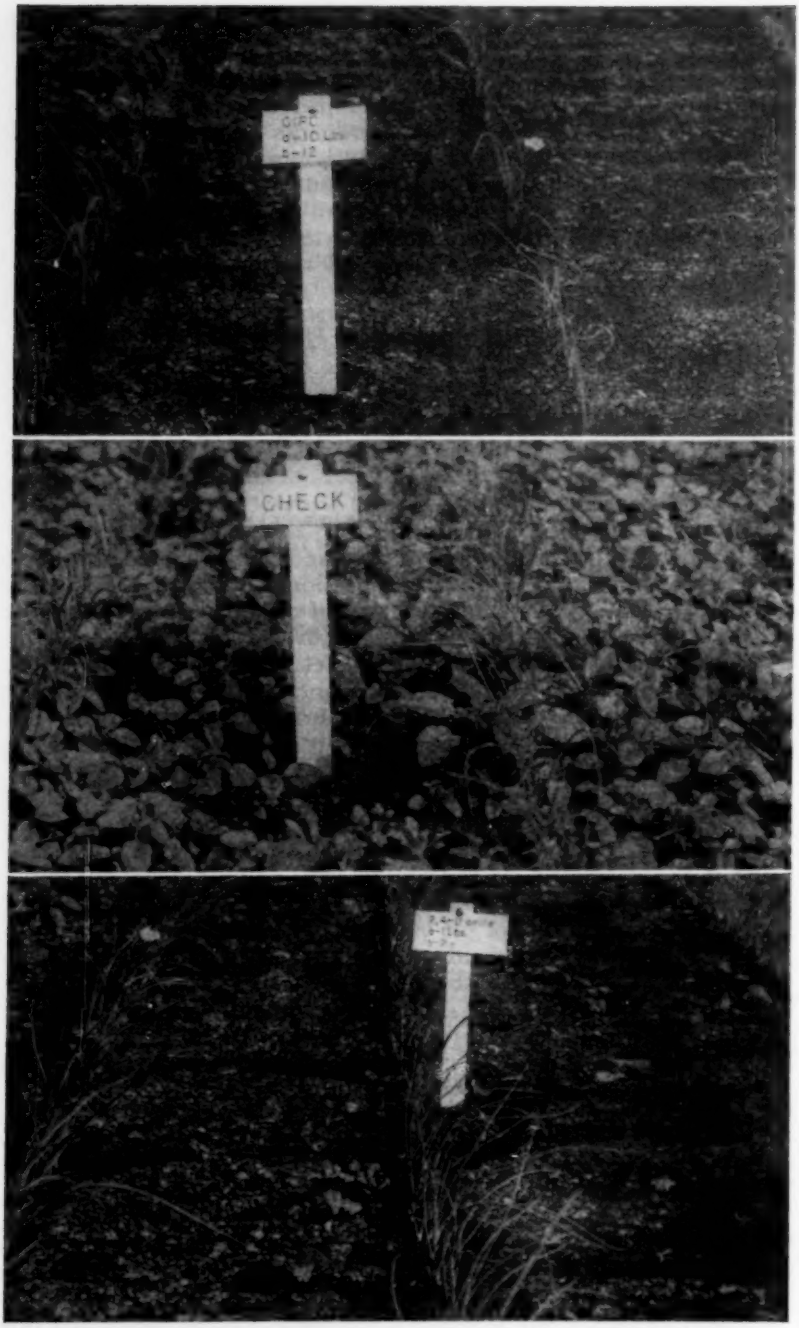

FIG. 1. The effect of pre-emergence treatments with 12 lbs/A of Chloro IPC and 2 lbs/A of 2,4–D amine as compared with the uncultivated check plot.

some extent be the reason for the outstanding results in the control of weeds with Chloro IPC and 2,4–D amine in this experiment.

The fact that Cloro IPC, 2,4–D, NIX, and Oktone produced a decrease in yields seems to be due at least in part to their effect on the stand of the onion plants. Table 4 presents a summary on stand counts made 45 days after seeding. Stand of onion plants in the 2,4–D, NIX, Chloro IPC and Oktone treated plots was significantly less than the check. Onion stand in the diesel oil and Stoddard solvent treated plots did not differ significantly from the check. This is in agreement with the lack of residual effect of these herbicides. It appears that the trend to lower yields in the treatments with diesel oil and Stoddard solvent (Table 2 and 3) is probably due to early weed competition.

Table 4. Stand of onion plants 45 days after seeding in relation to various pre-emergence herbicidal treatments and to three different depths of planting.

Herbicide	Planting depth in inches			Total stand
	Shallow ½	Medium 1	Deep 1½	
2,4-D	2628	2682	1878	7188**
NIX	2454	2486	2141	7117**
Diesel oil	3060	2744	2394	8198
Stoddard Solvent	3069	2832	2352	8253
Chloro IPC	2171	2399	2203	6773**
Oktone	2444	2220	1566	6230**
Check	3105	2629	2449	8183
Depth total	18931*	17992*	14983*	

*Significantly different, L.S.D. (.05) = 747.
**Significantly different from check. Also, Oktone reduced stand significantly from the rest of the chemical treatments. L.S.D. (.05) = 492.
L.S.D. for interaction of chemical treatment and depth of 5% level = 275.

The interaction of kind of herbicide to the concentrations of the herbicides used is significant. Chloro IPC and 2,4–D, reduced significantly the stand of the onion plants at the higher concentration used.

A significant reduction in stand occurred in the case of the 1½-inch depth compared with the 1- and the ½-inch depths and also in the case of 1-inch depth when compared with ½-inch. There was a better stand with the ½-inch planting depth when the stand totals for all the treatments were taken.

Study of the interaction between herbicidal treatment and depth of seeding on the stand of onion plants indicates a significant decrease in the number of onion plants in the Chloro IPC treatment for the shallow seeding depth in comparison with the medium and deep seedings. There was no difference in stand between the medium and deep depths with Chloro IPC. A significantly better stand of onions was obtained with the medium depth of seeding for the 2,4–D treatment than either the shallow or deep seedings. Comparison of stands of the corresponding depths for the Chloro IPC and 2,4–D treatments indicates that 2,4–D produced a significant reduction in the number of onion plants with the 1½-inch depth. However, both chemicals—2,4–D and Chloro IPC—gave the best stand

when seeded at one-inch depth. In general, as the residual toxicity of the herbicide is less, the stand of the onion plants is in favor of the shallow depth of seeding.

Approximately six weeks before harvest, a purple blotch disease appeared on the onion plants despite the usual weekly fungicide applications which produced some check in growth.

At the end of the storage period no differences were found that could be attributed to the herbicidal treatment.

Post-emergence experiments

Results of the two post-emergence experiments were about the same, therefore, in the following discussion no attempt will be made to separate the two post-emergence experiments. The direct application of the herbicides onto the onion plants and weeds in all cases produced burning of the onion leaves. Spot application of the chemicals also produced burning of the onion leaves contacted and reduction in the rate of growth was conspicuously visible after each treatment. The reduction in growth was apparently correlated to the severity of the burning of the chemical although the leaf injury was only of temporary nature. Chemicals which produced less burning of leaves also produced better yields, although the yields in all the herbicide-treated plots were significantly reduced. Table 5 presents yield data of the two post-emergence experiments. The control of weeds was excellent with CMU, good with the other treatments with the exception of Sinox W, which did not control the weeds (mostly sticker-weed, *Amaranthus spinosus L.*) but produced severe injury to the onions.

Table 5. Total yields in pounds of marketable onion bulbs in relation to post-emergence herbicidal applications in two experiments.

Experiment	Date seeded	Treatments†								
		KCNO	H_2SO_4	NIX	CIPC	CMU	End.	CIPC+KCNO	Check	L.S.D. at 5%
I	11/14/52	602	837	758	—	—	—	—	1012*	175
II	12/26/52	288	396	242	231	423	109	94	537*	95

†Sinox W produced severe injury to the onions and no marketable bulbs were obtained from this treatment.
*Significantly greater at 5% level from all the chemical treatments.

Reduction in yield in the herbicidal treatments is probably due to two major causes. One is the frequent burning of the leaves which checked growth; when bulbing time was reached, the onion plants did not have enough size for the production of large bulbs. This factor plus the relatively late planting in the second post-emergence experiment in comparison with the first probably accounts for the severe reductions in yield. The second probable reason for the reduction in yields is the effect of the chemicals on the stand of the plants. Stand counts of the onions were not taken, but observation indicated that some plants died as a result of the severe burning.

Sulphuric acid plots yielded significantly better than those treated with potassium cyanate. In the second post-emergence experiment, plots treated with CMU and sulphuric acid gave significantly better yields than the rest of the chemical treatments. CMU furthermore produced relatively little burning of the onion leaves.

Climatic conditions were varied at each post-emergence application. The effect of CMU on weeds seemed to be unaltered by variation in temperature or rainfall within the limits of this experiment. Sulphuric acid seemed to give better kill when applied in direct sunlight whether or not rain fell a few hours later. KCNO appeared to produce better kill when applied late in the afternoon and when rain did not occur for one day or more after the application. High temperatures (preferably above 70° F.) with no rain for 12 hours following application, are required for best kill of weeds when using NIX.

Storage of the bulbs for about a month and a half failed to show any differences in storage quality due to the treatments. Losses due to storage amounted to only 4.2 per cent for the first post-emergence experiment. The quality, color, and shape of the bulbs were excellent and no differences were found between the treatments.

SUMMARY

One pre-emergence and two post-emergence experiments were conducted for the control of weeds in Texas Early Grano variety of onions grown on Everglades peat soil during the winter and spring of the 1952–53 season.

In the pre-emergence experiment the most lasting and best weed control was obtained with Chloro IPC at 12 pounds per acre; 2,4–D amine at 2 pounds per acre was next best. Oktone controlled weeds quite well but its residual effect disappeared rapidly when compared with Chloro IPC and 2,4–D, and it reduced stand more severely than the 2,4–D or Chloro IPC. Stoddard solvent was the least effective, followed closely by the diesel oil treatment. The effect of NIX was intermediate between diesel oil and Oktone. DNOSBP at 1.5 and 3.0 pound rates killed the onion seedlings before they emerged from the soil. Yields of marketable bulbs were significantly reduced in all the herbicide treatments when compared with the hand weeded check. Yields of the herbicidal-treated plots were not significantly different; however, there was a strong trend to better yields with the use of higher concentrations of herbicides except Chloro IPC.

In the post-emergence experiments, control of weeds was excellent in the case of CMU at 2 pounds acre, and good in the case of sulphuric acid at 2.5 percent, potassium cyanate, NIX, Chloro IPC, Endothal 3003, and the mixture of Chloro IPC and potassium cyanate. Sinox W did not control the weeds and damaged the onions severely. Severe burning of the leaves of the onion plants occurred for all the chemical treatments and yields were reduced significantly in comparison with the check. Sulphuric acid and CMU, in general, gave lowest yield reduction.

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Precision Sprayer for Small Plots

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A number of portable spray systems have been designed for application of herbicides to experimental small plots (1, 4, 7). Several have been designed for special purposes or conditions which confronted the experimenter. Buchholtz (2), Robinson and Dunham (3), and Davis (8) described portable small plot sprayers for use where the experimental areas were small or no gain in precision was found by using more than rod-row plots. In general these and other spray systems have some deficiencies, which are accentuated when the equipment is to be used in small plot experiments requiring a high degree of precision. The equipment described here (Fig. 1) was designed to spray plots 3′ x 18′ and smaller. If the plot size is greatly increased the utility of this unit in its present design is materially reduced. Other factors desirable for larger size plots have necessarily been sacrificed in order to enhance qualities deemed more essential for the precision small plot work.

The precision sprayer offers the following advantages: (a) It can be completely cleaned or decontaminated readily (b) It is light weight and compact (c) It is completely portable with a self contained power supply (d) It permits consistent reproduction of a spray pattern and droplet size range (e) It can be employed to apply uniform low volume sprays to small plots (f) It affords precise control for application of a given rate of herbicide per unit area.

The complete precision portable sprayer unit (Fig. 1) weighs approximately 20 lbs. and may be carried by hand or modified by addition of shoulder straps for use on the worker's back. The ⅜″ plywood box housing the air cleaner, motor, pump and 6 volt wet battery measures 12¾″ x 10¾″ x 6¾″.

The Gast oilless rotary vacuum pump manufactured by the Gast Mfg. Corp. at Benton Harbor, Mich. is rated at 14 liters/min. at six inches of water suction. The unit as purchased includes a mounting with a Kendrick Davis 6 volt direct current motor. The pump unit, complete with filter and filter bottles, costs $66.00. The small Willard Storage battery (BB-207/U) is rated at 6 volts and 22.0 ampere hrs. with a unit cost of about $12.50. The cost of suitable atomizers varies from $3.75 for the DeVilbiss No. 151 to $45.00 for a Peet Grady Insecticide Atomizer (Fig. 1) also made by DeVilbiss. The latter is fitted with a "cut-off". The cut-off No. 631 shown with No. 151 atomizer in Figure 1 is priced at $5.00. The total cost of this precision small plot sprayer is somewhat under $100.00. This cost may be slightly higher than that required for modification of a knapsack sprayer but the advantages that the unit offers for precision small plot work far outweigh the additional investment.

Probably the most serious deficiency found in various sprayers is encountered in attempting to purge a highly active herbicide from

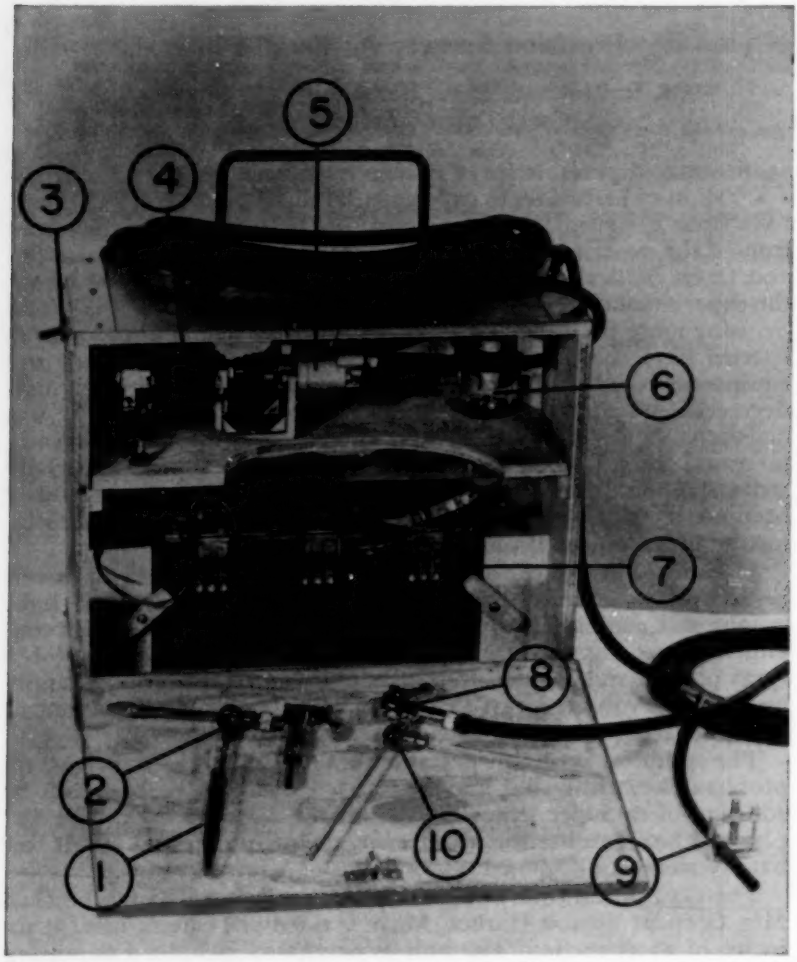

FIG. 1. Precision small plot sprayer. (1) 15 cc centrifuge tube. (2) Peet Grady insecticide atomizer. (3) Off-on control switch. (4) 6 volt motor. (5) Centrifical pump. (6) Air cleaner on intake line. (7) 6 volt wet battery. (8) DeVilbiss cut-off No. 631. (9) Screw clamp and bleeder line to regulate air flow. (10) DeVilbiss atomizer No. 151.

the solution containers, the hose, and the nozzles of the equipment. It is rather difficult to remove test compound residues from some small plot sprayers, especially when the surface area with which the chemical solution comes in contact is large. A sizeable quantity and repeated use of cleaning solvent is required to avoid contamination between different chemicals. Such spray systems have been found useful, however, for large demonstration areas requiring a minimum of precision. Buchholtz (2) and Robinson (3) found it desirable from a decontamination standpoint to have separate tank

and boom assemblies for different chemicals. DeRose (6) observed that some carbamates were adsorbed by plastics such as those occasionally used in hoses connecting solution containers and spray nozzles. The adsorbed material could be eluted from the plastic thus posing a source of contamination of different chemical solutions.

In the spray system illustrated in Fig. 1 an atomizer is used to disperse the spray solution. All parts exposed to contamination during operation are glass or chrome-plated metal which are non-adsorbent and are readily cleansed with an organic solvent or water depending on the chemical involved. Some discretion should be exercised in the choice of the decontaminating solution. Amino triazole, maleic hydrazide, and salts of organic compounds could be most easily removed from equipment with water while carbamates, ureas, and esters of various organic compounds would require a solvent such as acetone for dissolution.

The droplet size and spray pattern may be varied to suit the particular problem at hand. Patterns may be varied by using different types of atomizers. Figure 2 illustrates three variations in the average droplet size obtained with a DeVilbiss No. 151 atomizer. These variations were produced by adjusting the screw clamp on the bleeder in the compressed air line. By opening the bleeder, the air flow at the atomizer is reduced which in turn increases the average droplet size.

It is difficult to control drift of small spray particles. A movable spray chamber such as that illustrated and described by Ennis (7) is essential when fine droplet sprays are being applied to small experimental plots. A ten percent drift of the spray solution may mean the difference between injury and no injury to the crop plant in which weed control studies are being conducted.

Various types of containers may be used in connection with the atomizer, however, centrifuge tubes have proven to be the most satisfactory. The pointed or conical type makes possible complete removal of spray solutions other than that which wets the sides of the tube. In practice, these tubes have been filled with formulated spray solutions in the laboratory, stoppered, labeled, and transported to the field in test tube racks.

The "cut-off" attached to the DeVilbiss No. 151 atomizer shown in Figure 1 is not necessary but it greatly facilitates plot spraying. The "cut-off" gives the operator instant control over delivery of the spray material. The Peet Grady Insecticide Atomizer includes the "cut-off" when purchased.

Small plot sprayers such as that designed by Shaw require rather dilute solutions which consequently deliver a high volume per acre. These high volumes may not be representative of those to be used in the currently available field equipment. With the precision small plot sprayer, excellent coverage may be obtained by applying only 4 cc of solution per sq yd. A 4 cc/sq yd volume of solution is equivalent to 5.1 gal/A. The volume application per sq yd may be adjusted upward to conform to volumes which one contemplates using in

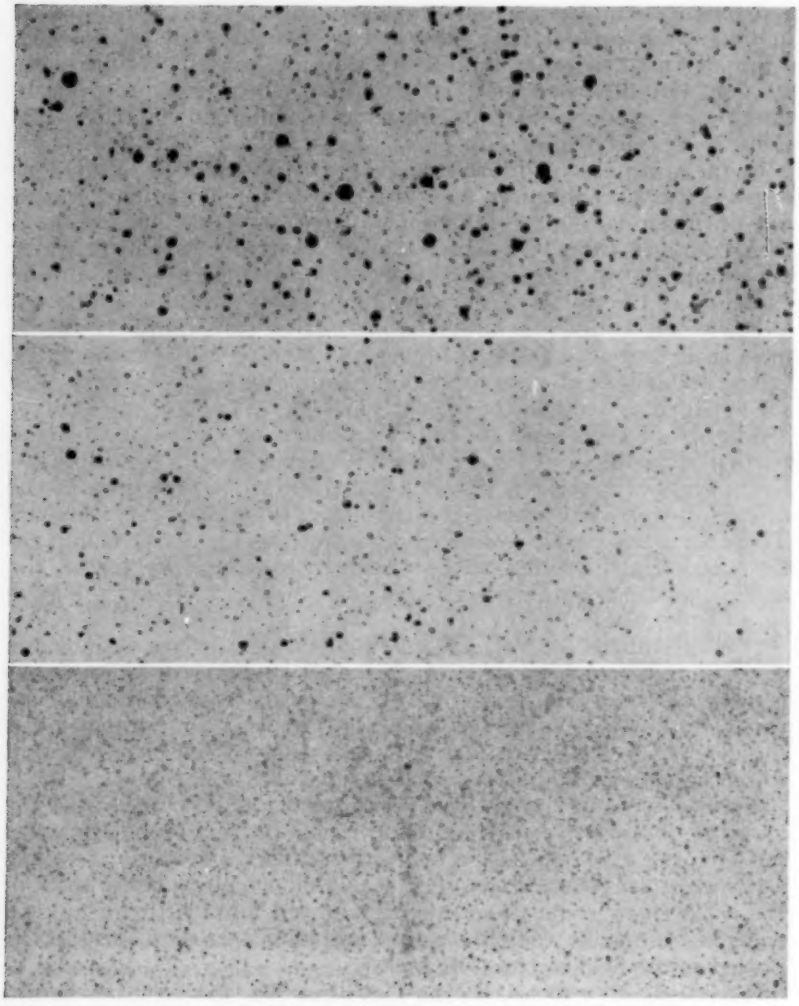

FIG. 2. Three variations in droplet size produced by varying the air flow through DeVilbiss atomizer No. 151.

large scale weed control tests while the rate per acre of the chemical application can be precisely regulated by adjusting the concentration of the herbicide in the solvent.

To insure complete plot coverage with the precision small plot sprayer it requires some degree of skill on the part of the operator. This technique is obtained only through practice. The most satisfactory method devised to develop skill in use of the equipment involves the delination of the plot area on some flat surface. A solution is then prepared which contains a dye and the solvent one intends

to use in the subsequent experiments. Sample cards are then placed in the delineated area and the dye solution is sprayed. The uniformity may then be checked by comparative observation of the sample cards.

This precision small plot sprayer has been used successfully in the field during the past three growing seasons. It has also performed excellently for a similar period in greenhouse experiments. Its compact portable power supply permits experimentation with small field plots located far from external power sources.

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News and WEED Affairs

As of February 1, 1954, Dr. Marion W. Parker assumed the responsibilities as Head of the Weed Investigation Section, Field Crops Research Branch, Agricultural Research Service, replacing Dr. Roy L. Lovvorn who resigned September 1, 1953, to accept the position of Director of Resident Instruction at North Carolina State College. Dr. Parker's career as a plant scientist in the Department of Agriculture has been outstanding. His training in plant physiology and biochemistry, his studies on the mechanism of the photoperiodic reaction, his recognition of the importance of balance between fundamental and applied research, and his administrative experience make him well qualified for his new responsibilities. We wish him every success in his new position.

Effective February 1, 1954, Dr. W. B. Ennis, Jr., assumed the responsibilities as Regional Coordinator of weed control research in the Southern Region, with headquarters at State College, Mississippi. In this new work he will continue to conduct research studies on fundamental aspects of weed control in addition to his duties as Regional Coordinator.

Mr. Everett B. Hollingsworth, currently completing the requirements for a M.S. degree in weed control at Mississippi State College, has been appointed to the position of Assistant Plant Physiologist, Department of Plant Pathology and Physiology, Mississippi Agricultural Experiment Station, State College, Mississippi, effective February 1, 1954. He will conduct studies in chemical weed control with emphasis on the behavior of herbicides in soils.

The Sixth Annual California Weed Conference met in Sacramento on January 27–28, 1954. The officers for the coming year are:

President—L. J. Berry, Ext. Range Spec., University of California, Davis, Calif.

Vice President—Paul Dresher, American Chemical Paint Co., San Jose, Calif.

Treasurer—James Koehler, California State Dept. of Agriculture, Los Angeles, Calif.

Secretary—O. A. Leonard, Botany Dept., University of California, Davis, Calif.

The next conference will be held on January 26–27, 1955 in Santa Barbara. The headquarters will be the Carrillo Hotel.

Proceedings are available from the secretary at a price of $1.50 each plus $.25 for postage. Some of the earlier proceedings are still available. The first and second are obtainable at $.50 each while the 4th, 5th and 6th can be had for $1.50.

At a meeting of Delegates of the Association of Regional Weed Control Conferences in Kansas City in December 1953, the following officers were elected for 1954:

President—Dr. Robert Beatty, American Chemical Paint Co., Ambler, Pa.

Vice President—Dr. William B. Ennis, Jr., Agent, Section of Weed Investigations, U.S.D.A., State College, Mississippi.

Secretary-Treasurer—Dr. Warren C. Shaw, Section of Weed Investigations, U.S.D.A., Beltsville, Maryland.

On June 30, Professor J. W. Zahnley retires from the faculty of Kansas State College where he is a member of the staff of the Agronomy Department. His association with the College as a staff member began in 1914 when he taught a course in methods of teaching agriculture.

Professor Zahnley has taught weed identification and control, and has played a major role in directing the research work in weed control at Kansas State College since 1925.

In 1950, Mr. Zahnley was presented an honorary membership in the North Central Weed Control Conference in recognition of his outstanding contributions to the field of weed control and his participation in the organization and direction of the Conference. He was honored at the 1954 Annual Kansas State Weed Conference for his contributions to weed control and the Kansas noxious weed program.

Professor Zahnley's successor in teaching and conducting weed control research is Professor L. E. Anderson who joined the Kansas State College Agronomy Department in September, 1953. Mr. Anderson is a former rural school teacher who received his BS and MS degrees from the University of Minnesota in 1947 and 1953, respectively. He was on the staff of the University of Minnesota as a teacher and research worker from 1947 until joining the Kansas State faculty. Professor Anderson is presently preparing a Ph.D. thesis for the University of Minnesota on the subject, "The Effect of Aqueous Solutions of MCP Applied to the Shoot Apex of Redwood Flax."

Delegates to the ARWCC for the coming year are listed below:

1. Western Weed Control Conference (WWCC)
   W. S. Ball—State Dept. of Agriculture, Sacramento, Calif.
   W. A. Harvey—Dept. of Botany, Agricultural Extension Service, University of California, Davis, Calif.
2. North Central Weed Control Conference (NCWCC)
   C. J. Gilbert—State Dept. of Agriculture, Brookings, S. D.
   Oliver C. Lee—Dept. of Botany, Purdue University, Lafayette, Ind.
3. Northeastern Weed Control Conference (NWCC)

R. H. Beatty—American Chemical Paint Company, Ambler, Pa.
A. O. Kuhn—Dept. of Agronomy, University of Maryland, College Park, Md.

4. Southern Weed Conference (SWC)
W. B. Ennis, Jr.—Section of Weed Investigations, Mississippi State College, State College, Miss.
E. G. Rodgers—Dept. of Agronomy, University of Florida, Gainesville, Fla.

Officers of the Four Regional Weed Control Conferences are as follows:

1. Western Weed Control Conference (WWCC)
President—W. S. Ball, State Dept. of Agriculture, Sacramento, Calif.
Vice President—W. A. Harvey, Department of Botany, Agri. Extension Service, Univ. of Calif., Davis, Calif.
Secretary-Treasurer—W. C. Robocker, Section of Weed Investigations, University of Nevada, Reno, Nevada.
2. North Central Weed Control Conference (NCWCC)
President—Oliver C. Lee, Department of Botany, Purdue University, Lafayette, Ind.
Vice President—B. H. Grigsby, Department of Botany, Michigan State College, East Lansing, Mich.
Secretary-Treasurer—F. W. Slife, Department of Agronomy, University of Illinois, Urbana, Ill.
3. Northeastern Weed Control Conference (NWCC)
President—A. O. Kuhn, Department of Agronomy, University of Maryland, College Park, Md.
Vice President—J. D. Van Geluwe, GLF, Soil Building Service, Ithaca, New York.
Secretary—R. J. Aldrich, Section of Weed Investigations, Farm Crops Dept., Rutgers University, New Brunswick, N. J.
Treasurer—D. A. Schallock, Farm Crops Dept., Rutgers University, New Brunswick, N. J.
4. Southern Weed Conference (SWC)
President—W. C. Shaw, Section of Weed Investigations, Plant Industry Station, Beltsville, Md.
Vice President—G. C. Klingman, Department of Agronomy, North Carolina State College, Raleigh, N. C.
Secretary-Treasurer—E. G. Rodgers, Department of Agronomy, University of Florida, Gainesville, Fla.

BIBLIOGRAPHY OF WEED INVESTIGATIONS
for July, August, and September 1953

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Prepared By

Division of Weed Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Section of Weed Investigations does not assume responsibility for the subject matter cited.

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